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Evaluation of High-Protein Distillers Dried Grains on Growth Performance and Carcass Characteristics of Growing-Finishing Pigs

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Evaluation of High-Protein Distillers Dried Grains on Growth Performance and Carcass Characteristics of Growing-Finishing Pigs

Abstract

A total of 1,890 growing-finishing pigs (PIC; 359 × 1050; initially 59.8 ± 1.3 lb) were used in a 124-d growth trial to compare the effects of high-protein distillers dried grains (HPDDG) or conventional distillers dried grains with solubles (DDGS) on growth performance and carcass characteristics. Conventional DDGS contained 29.0% CP, 0.48% standardized ileal digestible (SID) Lys, and 9.2% oil, whereas HPDDG contained 39.3% CP, 0.68% SID Lys, and 11.1% oil. All diets were formulated on an equal SID Lys-basis with diets containing HPDDG having less soybean meal than diets with conventional DDGS. There were 27 pigs per pen and 14 pens per treatment. Treatment diets were corn-soybean meal-based and arranged in a 2 × 2 + 1 factorial with main effects of DDG source (conventional DDGS or HPDDG) and level (15 or 30%). A corn-soybean meal-based diet served as the control and allowed linear and quadratic level effects to be determined within each DDG source. Pens of pigs were assigned to 1 of the 5 treatments in a randomized complete block design with initial weight as a blocking factor. Data were analyzed using the lme4 package in R (version 3.5.2) with pen as experimental unit. Overall, there were no differences observed in ADG between pigs fed either DDG source or level. Pigs fed HPDDG had decreased (linear, $P < 0.001$) ADFI and improved F/G compared with those fed conventional DDGS. Increasing either conventional DDGS or HPDDG decreased carcass yield and HCW (linear, $P < 0.02$); however, there were no differences between pigs fed HPDDG or conventional DDGS. Iodine value (IV) was greater ($P < 0.001$) in pigs fed HPDDG than conventional DDGS, and IV increased (linear, $P < 0.02$) with increasing DDG source. In summary, these data suggest that pigs fed HPDDG had better F/G, but greater IV compared with pigs fed conventional DDGS, probably due to the difference in oil content.

Keywords

distillers dried grains with solubles, finishing pigs, high protein distillers dried grains

Cover Page Footnote

The authors would like to thank ICM, Colwich, KS, for providing the high-protein distillers dried grains and partial financial support.

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Evaluation of High-Protein Distillers Dried Grains on Growth Performance and Carcass Characteristics of Growing-Finishing Pigs[1]

Zhong-Xing Rao, Robert D. Goodband, Mike D. Tokach, Steve S. Dritz,[2] Jason C. Woodworth, Joel M. DeRouchey, Hilda I. Calderón,[3] and Mallorie F. Wilken[4]

Summary

A total of 1,890 growing-finishing pigs (PIC; 359 × 1050; initially 59.8 ± 1.3 lb) were used in a 124-d growth trial to compare the effects of high-protein distillers dried grains (HPDDG) or conventional distillers dried grains with solubles (DDGS) on growth performance and carcass characteristics. Conventional DDGS contained 29.0% CP, 0.48% standardized ileal digestible (SID) Lys, and 9.2% oil, whereas HPDDG contained 39.3% CP, 0.68% SID Lys, and 11.1% oil. All diets were formulated on an equal SID Lys-basis with diets containing HPDDG having less soybean meal than diets with conventional DDGS. There were 27 pigs per pen and 14 pens per treatment. Treatment diets were corn-soybean meal-based and arranged in a 2 × 2 + 1 factorial with main effects of DDG source (conventional DDGS or HPDDG) and level (15 or 30%). A corn-soybean meal-based diet served as the control and allowed linear and quadratic level effects to be determined within each DDG source. Pens of pigs were assigned to 1 of the 5 treatments in a randomized complete block design with initial weight as a blocking factor. Data were analyzed using the lme4 package in R (version 3.5.2) with pen as experimental unit. Overall, there were no differences observed in ADG between pigs fed either DDG source or level. Pigs fed HPDDG had decreased (linear, $P < 0.001$) ADFI and improved F/G compared with those fed conventional DDGS. Increasing either conventional DDGS or HPDDG decreased carcass yield and HCW (linear, $P < 0.02$); however, there were no differences between pigs fed HPDDG or conventional DDGS. Iodine value (IV) was greater ($P < 0.001$) in pigs fed HPDDG than conventional DDGS, and IV increased (linear, $P < 0.02$) with increasing DDG source. In summary, these data suggest that pigs fed HPDDG had better F/G, but greater IV compared with pigs fed conventional DDGS, probably due to the difference in oil content.

[1] The authors would like to thank ICM, Colwich, KS, for providing the high-protein distillers dried grains and partial financial support.

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Introduction

Distillers dried grains with solubles is a co-product of the ethanol industry that is widely used in growing-finishing swine diets. Recently, new processing techniques are available to remove fibrous components before fermentation that produce a high-protein distillers dried grains (HPDDG) with approximately 40% crude protein. The new product generated has a different chemical composition and nutritive value for swine diets than conventional DDGS. Therefore, it is critical to characterize the effects of HPDDG on growth performance and carcass characteristics of growing-finishing pigs.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at a commercial research-finishing site in southwest Minnesota. The barn was naturally ventilated and double-curtain-sided. Each pen was equipped with a 5-hole stainless steel dry self-feeder and a bowl waterer for *ad libitum* access to feed and water.

Two groups of approximately 945 pigs (1,890 total pigs; PIC 359 × 1050; initially 59.8 ± 1.3 lb) were used in a 124-d growth trial. Pigs were housed in mixed gender pens with 27 pigs per pen and 14 pens per treatment (7 replications per barn). Daily feed additions to each pen were accomplished using a robotic feeding system (FeedPro, Feedlogic Corp., Wilmar, MN) able to record feed amounts for individual pens. The treatments were structured as a randomized complete block design and arranged in a 2 × 2 +1 factorial with main effects of DDG source (conventional DDGS and HPDDG) and level (15 or 30%). A corn-soybean meal-based diet served as the control and allowed linear and quadratic level effects to be determined within each DDG source. Nutrient and SID amino acid values for DDGS were derived from NRC[5] and nutrient and SID amino acid values for HPDDG were derived from Rho.[6] Conventional DDGS contained 29.0% CP, 0.48% standardized ileal digestible (SID) Lys, and 9.2% oil, whereas HPDDG contained 39.3% CP, 0.68% SID Lys, and 11.1% oil. All diets were formulated on an equal SID Lys-basis with diets containing HPDDG having less soybean meal than diets with conventional DDGS. Corn, conventional DDGS, and HPDDG used in this trial were analyzed for proximate analysis, amino acid profile (Table 1), and mycotoxins (Table 2). Dietary treatments were offered in 4 phases based on body weight (Tables 3 and 4). By design, NE was not balanced between treatments for each phase. Thus, differences in feed efficiency would reflect differences in energy value of the DDG source. In addition, dietary branched-chain amino acid (BCAA) ratios were adjusted based on the equation of Cemin et al.[7] to account for the excess dietary leucine in the conventional DDGS and HPDDG. The formulated dietary SID Ile:Lys, Leu:Lys, and Val:Lys ratios increased as the level of conventional DDGS or HPDDG increased. Diets with HPDDG had greater ratios compared to conventional

[5] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.

[6] Rho, Y., C. Zhu, E. Kiarie, and C. F. M de Lange. 2017. Standardized ileal digestible amino acids and digestible energy contents in high-protein distiller's dried grains with solubles fed to growing pigs. J. Anim. Sci. 95(8):3591-3597.

[7] Cemin, H. S., M. D. Tokach, S. S. Dritz, J. C. Woodworth, J. M. DeRouchey, and R. D. Goodband. 2019a. Meta-regression analysis to predict the influence of branched-chain and large neutral amino acids on growth performance of pigs. J. Anim. Sci. 97(6):2505-2514. doi: 10.1093/jas/skz118.

DDGS at the same inclusion level (15 or 30%) because of the greater Ile, Leu, and Val concentration in HPDDG. The difference in BCAA ratios were also a result of the higher CP level of HPDDG that resulted in lower SBM levels compared to the diet with DDGS.

Pigs were weighed approximately every 14 days from d 0 to 124 of the trial to determine ADG, ADFI, and F/G. On d 103, the 3 heaviest pigs in each pen were selected and marketed. These pigs were included in the growth performance data but not in carcass data. On the last day of the trial, final pen weights were taken, and the remaining pigs were tattooed with a pen identification number and transported to a USDA-inspected packing plant (JBS Swift, Worthington, MN) for carcass data collection. Carcass measurements included HCW, loin depth, backfat, percentage lean, and fat iodine value (IV). Fat samples for IV were collected from the shoulders of carcasses of 14 pigs per treatment. Percentage lean was calculated from a plant proprietary equation. Carcass yield was calculated by taking the pen average HCW divided by the pen average final live weight obtained at the farm.

Data were analyzed as a randomized complete block design for two-way ANOVA using the lmer function from the lme4 package in R program (R Core Team, 2019) with pen considered the experimental unit, initial BW as blocking factor, and treatment as fixed effect. Phases 1 and 2 were combined to represent the grower phase, while phases 3 and 4 were combined and referred to as the finisher phase for growth performance analysis. Predetermined contrasts were used to evaluate the main effects and interactive effects of DDG source × level among treatments. These contrasts were also used to examine the linear and quadratic responses due to increasing DDG inclusion level within DDG source using the control diet (as 0% inclusion level) and the 15% and 30% diets. All results were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

High-protein distillers dried grains had a greater crude protein and fat content than conventional DDGS (Table 1). The fumonisin concentration measurements were higher in HPDDG than conventional DDGS and ranged from approximately 8 to 15 ppm vs. only 200 to 300 ppb in conventional DDGS. Zearalenone concentrations were also higher in HPDDG than conventional DDGS and ranged from 250 to 350 ppb in HPDDG to 100 to 145 ppb in conventional DDGS. Vomitoxin concentrations were generally similar among DDG sources and ranged from approximately 0.8 to 1.0 ppm (Table 2). Chemical analysis (Tables 3 and 4) of treatment diets for dry matter, crude protein, calcium, phosphorus, neutral detergent fiber, and ether extract were within formulated ranges.

In the grower phase (day 0 to 55), increasing either DDG source decreased (linear, $P < 0.001$) ADG (Table 5). In the finishing phase (day 55 to 124), increasing conventional DDGS tended to decrease (quadratic, $P < 0.065$) ADG. However, there were no differences observed in overall ADG. Despite no overall changes in ADG among treatments, increasing conventional DDGS or HPDDG decreased (linear, $P < 0.04$ and $P < 0.065$, respectively) final body weight (BW). Increasing HPDDG decreased (linear, $P \leq 0.002$) ADFI and improved F/G in both phases and the overall period, whereas there was no change in ADFI or F/G among pigs fed conventional DDGS. The improvement in F/G of pigs fed increasing HPDDG compared to conventional DDGS may be due to the higher oil content of HPDDG.

Based on the improved F/G and decreased ADFI in pigs fed HPDDG, its energy content appears to be greater than the conventional DDGS used in this study. The improvement in F/G of pigs fed increasing HPDDG compared to conventional DDGS may be due to the higher oil content or improved nutrient digestibility in HPDDG. By calculating the caloric efficiency (CE) of diets using procedures of Cemin et al.,[8] CE was linearly improved ($P = 0.033$) as the inclusion level of HPDDG increased. Therefore, we suspected that the net energy (NE) of HPDDG was underestimated. For CE of HPDDG diets to be identical to the control diet, the NE of HPDDG would have to be 103.4% of the energy of corn, which was greater than the value (97.3%)[8] used for diet formulation.

For carcass characteristics, increasing either conventional DDGS or HPDDG decreased carcass yield and HCW (linear, $P < 0.02$). There were no differences among dietary treatments in back fat, loin depth, or percentage lean. Carcass fat iodine value (IV) was greater ($P < 0.001$) in pigs fed HPDDG than conventional DDGS, and IV increased (linear, $P < 0.02$) with increasing either DDG source. Like the improvements in F/G, the change in IV between pigs fed HPDDG and conventional DDGS may be due to the differences in oil content.

In summary, these data suggest that feeding pigs up to 30% HPDDG may have economic advantages because of its amino acid profile and improved F/G compared with feeding pigs conventional DDGS. However, caution must be used with the type of HPDDG used because of the different nutrient profiles, especially AA profile, oil, and energy content. An accurate AA profile allows adjustment of SID Ile:Lys, Leu:Lys, Trp:Lys, and Val:Lys to avoid BCAA imbalance that may cause reduced growth performance. A potential concern with the HPDDG used in this study is the high oil content, which leads to increased carcass fat IV, resulting in higher unsaturated fat in the carcass. In addition, the dietary branched-chain amino acid ratio should be considered to maintain growth performance.

[8] Cemin, H. S., M. D. Tokach, S. S. Dritz, J. C. Woodworth, J. M. DeRouchey, and R. D. Goodband. 2019b. PSVI-20 Evaluating the productive energy content of high-protein distillers dried grains in swine diets. J. Anim. Sci. 97(Supplement_2):211-212. doi: 10.1093/jas/skz122.371.

Table 1. Chemical analysis of ingredients (as-fed basis)[1,2]

Item	Corn	Conventional DDGS	HPDDG
Proximate analysis, %			
Dry matter	86.53	90.15	92.62
Crude protein	6.73	29.03	39.17
Calcium	0.10	0.12	0.17
Phosphorus	0.33	1.08	0.73
Neutral detergent fiber	6.83	29.87	30.60
Ether extract	3.20	8.03	10.27
Indispensable amino acid, %			
Arginine	0.26	1.33	1.77
Histidine	0.18	0.84	1.08
Isoleucine	0.22	1.17	1.64
Leucine	0.69	3.34	4.69
Lysine	0.22	1.03	1.48
Methionine	0.12	0.51	0.82
Phenylalanine	0.29	1.50	2.08
Threonine	0.22	1.13	1.51
Tryptophan	0.05	0.22	0.33
Valine	0.29	1.48	2.06
Dispensable amino acid, %			
Alanine	0.43	1.90	2.73
Aspartic acid	0.42	1.79	2.63
Cysteine	0.14	0.58	0.76
Glutamic acid	1.06	3.53	5.79
Glycine	0.24	1.18	1.51
Proline	0.52	2.21	3.01
Serine	0.27	1.27	1.69
Taurine	0.10	0.07	0.08
Tyrosine	0.13	1.04	1.46

[1]Representative samples of each batch of each ingredient were collected, homogenized, and submitted for proximate analysis (Ward Laboratories, Inc., Kearney, NE) and amino acid analysis (Experiment Station Chemical Laboratories, University of Missouri, Columbia, MO). The result shown was the average of three batches of ingredients used.
[2]DDGS = dried distillers grain with solubles. HPDDG = high-protein dried distillers grain.

Table 2. Dietary mycotoxin concentrations (as-fed basis, ppb)[1,2,3]

Item	Corn	Conventional DDGS	HPDDG
Aflatoxin B1	< 20	< 20	< 20
Aflatoxin B2	< 20	< 20	< 20
Aflatoxin G1	< 20	< 20	< 20
Aflatoxin G2	< 20	< 20	< 20
Fumonisin B1	< 200	240.0	9234.3
Fumonisin B2	< 200	< 200	2949.7
HT-2 toxin	< 200	< 200	< 200
T-2 Toxin	< 20	< 20	< 20
Ochratoxin	< 20	< 20	< 20
Sterigmatocystin	< 20	< 20	< 20
Zearalenone	< 100	122.3	305.7
Vomitoxin	418.3	897.7	868.3

[1]Representative samples of each ingredient were collected for each batch. The result was reported as the average of three batches.
[2]Diet mycotoxin concentration was analyzed at North Dakota State University Veterinary Diagnostic Laboratory (Fargo, ND) by LC/MS/MS assay.
[3]DDGS = dried distillers grain with solubles. HPDDG = high-protein dried distillers grain.

Table 3. Composition of phase 1 and 2 diets (as-fed basis)[1]

	Phase 1					Phase 2				
		Conventional DDGS[2]		HPDDG			Conventional DDGS		HPDDG	
Items	Control	15%	30%	15%	30%	Control	15%	30%	15%	30%
Ingredients, %										
Corn	74.30	61.92	50.42	63.24	52.93	80.26	69.06	57.56	70.31	60.08
Soybean meal	22.52	20.14	16.82	18.94	14.42	16.91	13.27	9.94	12.07	7.54
Corn DDGS	--	15.00	30.00	--	--	--	15.00	30.00	--	--
HPDDG	--	--	--	15.00	30.00	--	--	--	15.00	30.00
Limestone, ground	1.00	1.13	1.23	1.10	1.20	0.95	1.05	1.15	1.05	1.13
Monocalcium phosphate	0.65	0.40	0.15	0.40	0.15	0.50	0.25	0.00	0.30	0.00
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
L-Lysine-HCl	0.48	0.50	0.55	0.50	0.55	0.44	0.50	0.55	0.50	0.55
DL-Methionine	0.14	0.08	0.03	0.02	0.00	0.10	0.05	0.00	0.00	0.00
L-Threonine	0.23	0.19	0.15	0.17	0.11	0.19	0.17	0.13	0.14	0.08
L-Tryptophan	0.05	0.05	0.05	0.04	0.04	0.05	0.05	0.05	0.05	0.04
L-Valine	0.11	0.08	0.08	0.07	0.08	0.09	0.09	0.10	0.06	0.07
Vitamin and trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Phytase[4]	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

continued

Table 3. Composition of phase 1 and 2 diets (as-fed basis)[1]

	Phase 1					Phase 2				
		Conventional DDGS[2]		HPDDG			Conventional DDGS		HPDDG	
Items	Control	15%	30%	15%	30%	Control	15%	30%	15%	30%
Calculated analysis										
Standardized ileal digestible (SID) amino acids, %[3]										
Lysine	1.13	1.13	1.13	1.13	1.13	0.96	0.96	0.96	0.96	0.96
Isoleucine:lysine	55	59	62	63	70	55	57	60	62	69
Leucine:lysine	113	134	153	151	186	119	141	163	161	203
Methionine:lysine	34	32	30	29	33	33	31	30	29	36
Methionine and cysteine:lysine	56	56	56	56	65	56	56	57	58	70
Threonine:lysine	65	65	65	65	65	65	65	65	65	65
Tryptophan:lysine	19.0	18.8	19.1	18.8	19.1	18.8	18.9	18.8	18.9	18.7
Valine:lysine	70	74	79	78	88	70	76	82	78	90
Lysine:net energy, g/Mcal	4.42	4.49	4.55	4.39	4.35	3.69	3.74	3.79	3.66	3.63
Net energy, kcal/lb	1,160	1,141	1,126	1,167	1,177	1,179	1,165	1,150	1,189	1,201
Crude protein, %	17.7	19.7	21.4	20.8	23.6	15.4	17.0	18.7	18.0	20.9
Calcium, %	0.61	0.63	0.63	0.61	0.61	0.55	0.55	0.55	0.55	0.53
STTD P, %	0.38	0.38	0.38	0.38	0.38	0.34	0.34	0.34	0.34	0.33
Proximate analysis, %[5]										
Dry matter	87.02	88.69	88.63	88.49	89.22	88.09	88.06	89.84	88.31	89.35
Crude protein	14.9	17.2	19.7	18.1	22.0	16.1	16.9	17.5	17.7	20.4
Calcium	0.60	0.53	0.53	0.52	0.48	0.58	0.50	0.53	0.48	0.45
Phosphorus	0.41	0.44	0.46	0.40	0.41	0.42	0.41	0.44	0.39	0.37
Neutral detergent fiber	7.2	10.4	13.8	9.2	14.2	7.6	10.6	12.8	9.7	13.8
Ether extract	2.9	3.9	4.5	4.3	5.6	3.1	3.9	4.9	4.4	5.4

[1]Phases 3 and 4 were fed from 60 to 110 and 110 to 160 lb, respectively.
[2]DDGS = dried distillers grain with solubles. HPDDG = high-protein dried distillers grain.
[3]Equation used for ADG (g/d) prediction (Cemin, H. S., M. D. Tokach, S. S. Dritz, J. C. Woodworth, J. M. DeRouchey, and R. D. Goodband. 2019a. Meta-regression analysis to predict the influence of branched-chain and large neutral amino acids on growth performance of pigs. J. Anim. Sci. 97(6):2505-2514. doi: 10.1093/jas/skz118.): − 985.94 + (15.2499 × average BW (kg)) − (0.08885 × average BW × average BW) + (1.063 × Leu:Lys) + (20.2659 × Ile:Lys) − (0.1479 × Ile:Lys × Ile:Lys) + (9.2243 × (Ile+Val):Leu) − (0.03321 × (Ile+Val):Leu × (Ile+Val):Leu) − (0.4413 × Ile:Trp).
[4]Optiphos 2000 (Huvepharma Inc. Peachtree City, GA) provided 389.6 units of phytase FTY/lb of diet with an assumed release of 0.11% STTD P.
[5]At least 6 representative samples of each diet were collected for each treatment, homogenized, and submitted for proximate analysis (Ward Laboratories, Inc., Kearney, NE).

Table 4. Composition of phase 3 and 4 diets (as-fed basis)[1]

	Phase 3					Phase 4				
		Conventional DDGS[2]		HPDDG			Conventional DDGS		HPDDG	
Items	Control	15%	30%	15%	30%	Control	15%	30%	15%	30%
Ingredients, %										
Corn	84.75	73.32	61.78	74.52	64.28	86.15	75.37	63.83	76.64	66.33
Soybean meal	12.52	9.19	5.87	8.00	3.47	11.29	7.17	3.85	5.97	1.45
Corn DDGS	--	15.00	30.00	--	--	--	15.00	30.00	--	--
HPDDG	--	--	--	15.00	30.00	--	--	--	15.00	30.00
Limestone, ground	0.93	1.03	1.13	1.03	1.10	0.90	1.00	1.10	1.00	1.10
Monocalcium phosphate	0.55	0.25	0.00	0.30	0.00	0.50	0.25	0.00	0.25	0.00
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
L-Lysine-HCl	0.40	0.45	0.50	0.45	0.50	0.38	0.45	0.50	0.45	0.50
DL-Methionine	0.06	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
L-Threonine	0.16	0.13	0.09	0.11	0.05	0.15	0.12	0.09	0.10	0.04
L-Tryptophan	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.04	0.04
L-Valine	0.06	0.07	0.06	0.04	0.04	0.04	0.07	0.06	0.03	0.02
Vitamin and trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Phytase[4]	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

continued

Table 4. Composition of phase 3 and 4 diets (as-fed basis)[1]

	Phase 3					Phase 4				
		Conventional DDGS[2]		HPDDG			Conventional DDGS		HPDDG	
Items	Control	15%	30%	15%	30%	Control	15%	30%	15%	30%
Calculated analysis										
Standardized ileal digestible (SID) amino acids, %[3]										
Lysine	0.82	0.82	0.82	0.82	0.82	0.77	0.77	0.77	0.77	0.77
Isoleucine:lysine	55	58	61	63	72	55	57	60	63	72
Leucine:lysine	127	153	179	176	225	132	157	185	182	234
Methionine:lysine	32	29	33	32	39	31	29	33	33	41
Methionine and cysteine:lysine	56	56	62	63	78	56	57	64	65	80
Threonine:lysine	65	65	65	65	65	65	65	65	65	65
Tryptophan:lysine	19.1	19.0	18.8	18.9	18.7	18.9	18.8	18.6	18.8	18.6
Valine:lysine	70	77	83	80	94	70	78	84	80	93
Lysine:net energy, g/Mcal	3.12	3.16	3.20	3.09	3.07	2.92	2.95	2.99	2.89	2.86
Net energy, kcal/lb	1,192	1,177	1,162	1,202	1,213	1,196	1,184	1,169	1,209	1,219
Crude protein, %	13.6	15.3	17.0	16.4	19.2	13.0	14.5	16.2	15.6	18.4
Calcium, %	0.54	0.53	0.53	0.53	0.51	0.51	0.51	0.51	0.51	0.51
STTD P, %	0.33	0.33	0.33	0.33	0.32	0.32	0.32	0.32	0.32	0.32
Proximate analysis, %[5]										
Dry matter	86.95	87.91	88.25	88.28	88.53	87.94	88.63	89.49	88.07	88.87
Crude protein	12.0	13.2	15.7	15.1	18.3	12.5	14.2	14.6	15.1	17.2
Calcium	0.57	0.58	0.45	0.51	0.58	0.55	0.49	0.45	0.55	0.50
Phosphorus	0.37	0.40	0.43	0.36	0.35	0.40	0.40	0.41	0.36	0.32
Neutral detergent fiber	7.8	9.0	13.3	10.5	12.7	7.7	10.9	12.1	10.5	12.6
Ether extract	3.5	3.9	4.8	4.5	5.5	3.5	4.4	4.7	4.7	5.4

[1]Phases 3 and 4 were fed from 160 to 220 and 220 lb to marketing, respectively.
[2]DDGS = dried distillers grain with solubles. HPDDG = high-protein dried distillers grain.
[3]Equation used for ADG (g/d) prediction (Cemin, H. S., M. D. Tokach, S. S. Dritz, J. C. Woodworth, J. M. DeRouchey, and R. D. Goodband. 2019a. Meta-regression analysis to predict the influence of branched-chain and large neutral amino acids on growth performance of pigs. J. Anim. Sci. 97(6):2505-2514. doi: 10.1093/jas/skz118.): – 985.94 + (15.2499 × average BW (kg)) – (0.08885 × average BW × average BW) + (1.063 × Leu:Lys) + (20.2659 × Ile:Lys) – (0.1479 × Ile:Lys × Ile:Lys) + (9.2243 × (Ile+Val):Leu) – (0.03321 × (Ile+Val):Leu × (Ile+Val):Leu) – (0.4413 × Ile:Trp).
[4]Optiphos 2000 (Huvepharma Inc. Peachtree City, GA) provided 389.6 units of phytase FTY/lb of diet with an assumed release of 0.11% STTD P.
[5]At least 6 representative samples of each diet were collected for each treatment, homogenized, and submitted for proximate analysis (Ward Laboratories, Inc., Kearney, NE).

Table 5. The effects of dried distillers grains source and level on grow-finish pig growth performance, and carcass characteristics[1]

							Probability, *R* =				
	Control	Conventional DDGS		HPDDG				Conventional DDGS		HPDDG	
Item[2]	(0%)	15%	30%	15%	30%	SEM	Source	Linear	Quadratic	Linear	Quadratic
BW, lb											
Initial	59.8	59.7	59.7	59.8	59.8	1.34	0.853	0.801	0.955	0.948	0.940
Ending	286.6	280.7	281.7	284.4	282.2	5.05	0.199	0.039	0.098	0.065	0.974
Grower phase[3]											
ADG, lb	1.97	1.94	1.90	1.93	1.88	0.035	0.249	< 0.001	0.831	< 0.001	0.772
ADFI, lb[5]	4.12	4.06	4.03	4.02	3.80	0.090	0.002	0.121	0.696	< 0.001	0.197
F/G[5]	2.09	2.09	2.12	2.09	2.02	0.017	< 0.001	0.157	0.374	< 0.001	0.092
CE, kcal/lb	2,447	2,412	2,414	2,458	2,404	20.3	0.271	0.164	0.353	0.071	0.109
Finisher phase[4]											
ADG, lb	1.89	1.84	1.91	1.90	1.92	0.045	0.166	0.571	0.065	0.368	0.858
ADFI, lb[6]	5.75	5.74	5.83	5.63	5.53	0.121	< 0.001	0.256	0.399	0.002	0.862
F/G	3.05	3.13	3.07	2.99	2.89	0.041	< 0.001	0.752	0.141	0.001	0.717
CE, kcal/lb	3,647	3,690	3,579	3,600	3,512	48.8	0.064	0.250	0.132	0.026	0.689
Overall											
ADG, lb	1.93	1.89	1.91	1.92	1.90	0.015	0.375	0.252	0.101	0.194	0.950
ADFI, lb[5]	4.99	4.95	4.98	4.88	4.72	0.066	< 0.001	0.902	0.422	< 0.001	0.603
F/G	2.58	2.62	2.61	2.54	2.48	0.027	< 0.001	0.296	0.390	< 0.001	0.596
CE, kcal/lb	3,060	3,065	3,019	3,039	2,987	32.5	0.225	0.220	0.380	0.033	0.606
Carcass characteristics											
HCW, lb	209.2	203.9	203.0	207.2	202.9	3.31	0.189	< 0.001	0.127	< 0.001	0.443
Carcass yield, %	73.1	72.6	72.1	72.9	71.9	0.324	0.920	0.019	0.849	0.005	0.231
Backfat depth, in[7]	0.62	0.61	0.63	0.62	0.61	0.011	0.978	0.954	0.241	0.421	0.699
Loin depth, in[7]	2.64	2.64	2.63	2.65	2.63	0.018	0.828	0.847	0.947	0.684	0.426
Lean, %[7]	57.2	57.5	57.2	57.3	57.4	0.181	0.978	0.901	0.272	0.552	0.909
Iodine value,[6] g/100 g	64.8	69.0	73.7	72.9	80.0	0.76	< 0.001	< 0.001	0.818	< 0.001	0.546

[1]A total of 1,890 pigs (initially 59.8 lb) were used in two groups with 27 pigs per pen and 14 replicates per treatment.
[2]BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed-to-gain ratio. CE = caloric efficiency (the amount of energy consumed per kg of BW gain). HCW = hot carcass weight.
[3]Grower phase was from d 0 to 55 in group 1 and from d 0 to 55 in group 2.
[4]Finisher phase was from d 55 to 113 in group 1 and from d 55 to 124 in group 2.
[5]Interactive effect, source × level $P \le 0.05$.
[6]Interactive effect, source × level $0.05 < P \le 0.10$.
[7]Adjusted using HCW as covariate.