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Effects of Corn Dried Distillers Grains with Solubles Withdrawal on Finishing Pig Performance

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Abstract

A total of 860 finishing pigs [C48 or L42 × 327; initially 146 ± 11.1 lb body weight (BW)] were used in a 76-d experiment to evaluate the effects of removing corn dried distillers grains with solubles (DDGS) from diets at varying intervals before harvest. Pigs were fed diets containing 40% DDGS until the start of the trial. Diets contained 35% DDGS from approximately 146 to 180 lb and 30% until the completion of the trial. Pen served as the experimental unit, and there were 7 replicate pens per treatment with 23 to 25 pigs per pen. Pens were blocked by BW within the barn and allotted to 1 of 5 dietary treatments differentiated by the number of days before slaughter that diets containing DDGS were withdrawn and replaced with corn-soybean meal-based diets. Withdrawal times consisted of the following: 76 (no DDGS fed), 42, 27, 15, or 0 d (no withdrawal) before the time all pigs were marketed. At the time of harvest, all pigs were sent to a commercial processing facility for carcass data collection. For the overall period from d -76 to 0, as time of DDGS withdrawal increased, average daily gain (ADG) and final BW also increased (linear, $P <$ 0.018), while feed:gain ratio (F/G) improved (quadratic, $P = 0.022$). Average daily feed intake (ADFI) quadratically decreased ($P = 0.030$) with increasing withdrawal time. There was a linear increase ($P =$ 0.009) in hot carcass weight (HCW), with a marginally significant increase in carcass yield (linear, $P =$ 0.094) with increasing DDGS withdrawal time. Loin depth and lean percentage did not demonstrate any evidence for treatment differences ($P > 0.132$). Backfat was linearly increased ($P = 0.030$) with a marginally significant ($P = 0.084$) quadratic response with increasing DDGS withdrawal time. Lastly, the iodine value of belly fat was increased (linear, $P < 0.034$) with increased feeding duration of DDGS.

Feed cost per pig and income over feed cost (IOFC) per all pigs that started on the experiment were increased (linear, $P < 0.048$) with increasing withdrawal time. Feed cost per lb of gain did not demonstrate evidence for treatment differences ($P > 0.505$). When based on the number of pigs marketed at the end of the experiment, feed cost per pig was increased (linear, $P = 0.001$) with increasing withdrawal time, though feed cost per lb of gain and IOFC did not have evidence for differences ($P > 0.186$). Carcass gain value was increased (linear, $P = 0.001$) with increased DDGS withdrawal time. In conclusion, removing pigs from DDGS for longer periods before slaughter increased ADG and improved F/G, resulting in increased HCW. Belly fat iodine value was inversely related to the length of DDGS withdrawal, with the highest iodine value (IV) resulting from pigs that consumed DDGS for the entire finishing period. The advantages in final BW and HCW seen in the present data may encourage producers to remove DDGS from finishing diets earlier than commonly practiced.

Keywords

dried distillers grains with solubles, DDGS, finishing pigs, withdrawal

Cover Page Footnote

Appreciation is expressed to Holden Farms, Inc. (Northfield, MN) for providing the animals, research facilities, and technical support.

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Allerson

Effects of Corn Dried Distillers Grains with Solubles Withdrawal on Finishing Pig Performance[1]

A.B. Lerner, M.D. Tokach, J.C. Woodworth, J.M. DeRouchey, S.S. Dritz,[2] R.D. Goodband, and M.W. Allerson[3]

Summary

A total of 860 finishing pigs [C48 or L42 × 327; initially 146 ± 11.1 lb body weight (BW)] were used in a 76-d experiment to evaluate the effects of removing corn dried distillers grains with solubles (DDGS) from diets at varying intervals before harvest. Pigs were fed diets containing 40% DDGS until the start of the trial. Diets contained 35% DDGS from approximately 146 to 180 lb and 30% until the completion of the trial. Pen served as the experimental unit, and there were 7 replicate pens per treatment with 23 to 25 pigs per pen. Pens were blocked by BW within the barn and allotted to 1 of 5 dietary treatments differentiated by the number of days before slaughter that diets containing DDGS were withdrawn and replaced with corn-soybean meal-based diets. Withdrawal times consisted of the following: 76 (no DDGS fed), 42, 27, 15, or 0 d (no withdrawal) before the time all pigs were marketed. At the time of harvest, all pigs were sent to a commercial processing facility for carcass data collection. For the overall period from d -76 to 0, as time of DDGS withdrawal increased, average daily gain (ADG) and final BW also increased (linear, $P < 0.018$), while feed:gain ratio (F/G) improved (quadratic, $P = 0.022$). Average daily feed intake (ADFI) quadratically decreased ($P = 0.030$) with increasing withdrawal time. There was a linear increase ($P = 0.009$) in hot carcass weight (HCW), with a marginally significant increase in carcass yield (linear, $P = 0.094$) with increasing DDGS withdrawal time. Loin depth and lean percentage did not demonstrate any evidence for treatment differences ($P > 0.132$). Backfat was linearly increased ($P = 0.030$) with a marginally significant ($P = 0.084$) quadratic response with increasing DDGS withdrawal time. Lastly, the iodine value of belly fat was increased (linear, $P < 0.034$) with increased feeding duration of DDGS.

Feed cost per pig and income over feed cost (IOFC) per all pigs that started on the experiment were increased (linear, $P < 0.048$) with increasing withdrawal time. Feed cost per lb of gain did not demonstrate evidence for treatment differences ($P > 0.505$).

[1]Appreciation is expressed to Holden Farms, Inc. (Northfield, MN) for providing the animals, research facilities, and technical support.

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When based on the number of pigs marketed at the end of the experiment, feed cost per pig was increased (linear, $P = 0.001$) with increasing withdrawal time, though feed cost per lb of gain and IOFC did not have evidence for differences ($P > 0.186$). Carcass gain value was increased (linear, $P = 0.001$) with increased DDGS withdrawal time. In conclusion, removing pigs from DDGS for longer periods before slaughter increased ADG and improved F/G, resulting in increased HCW. Belly fat iodine value was inversely related to the length of DDGS withdrawal, with the highest iodine value (IV) resulting from pigs that consumed DDGS for the entire finishing period. The advantages in final BW and HCW seen in the present data may encourage producers to remove DDGS from finishing diets earlier than commonly practiced.

Introduction

Corn DDGS are commonly added to swine diets as a means of reducing diet cost. This by-product can typically be incorporated into swine diets at 20 to 30% with no adverse effects on growth rate.[4] This allows producers to significantly reduce feed costs, particularly in grow-finish pigs. However, there are potential detrimental effects associated with the increased fiber and oil content of DDGS. Increased neutral detergent fiber (NDF) in the digestive tract increases gut fill and therefore can result in reduced carcass yield for pigs consuming DDGS compared to their counterparts consuming a diet with lower NDF.[5] Furthermore, increased oil content in DDGS compared to corn may result in poorer pork fat quality due to increased concentration of unsaturated fatty acids.[6] Jacela et al.[7] determined that a 3- or 6-week withdrawal did not impact growth performance but did significantly improve fat quality for pigs withdrawn from DDGS as measured by iodine value. Coble et al.[8] determined that feeding 30% DDGS for 20 d before slaughter decreased carcass yield compared to pigs not fed DDGS. Thus, it is important to understand the ideal timing of withdrawing DDGS and the subsequent impact on finishing pig growth performance, carcass characteristics, fat quality, and economics. The objective of this study was to understand the impacts of withdrawing DDGS starting 76 d before harvest or later in a commercial facility.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The trial was conducted at a commercial research facility owned and operated by Holden Farms, Inc. (Northfield, MN). The barn was

[4]DeDecker, J. M., M. Ellis, B. F. Wolter, J. Spencer, D. M. Webel, C. R. Bertelsen, and B. A. Peterson. 2005. Effects of dietary level of distiller's dried grains with solubles and fat on the growth performance of growing pigs. J. Anim. Sci. 83(Suppl. 2):79. (Abstr.).

[5]Turlington, W. H. 1984. Interactive effects of dietary fiber levels and environmental temperature on growing pigs. MS Thesis. University of Kentucky, Lexington.

[6]Whitney, M., G. Shurson, L. Johnston, D. Wulf, and B. Shanks. 2006. Growth performance and carcass characteristics of grower-finisher pigs fed high-quality corn distillers dried grain with solubles originating from a modern Midwestern ethanol plant. Journal of animal science 84(12):3356-3363.

[7]Jacela, J. Y., J. M. Benz, S. S. Dritz, M. D. Tokach, J. M. DeRouchey, R. D. Goodband, J. L. Nelssen, and K. J. Prusa. 2009. Effect of dried distillers grains with solubles withdrawal regimens on finishing pig performance and carcass characteristics. In: Proc. Swine Day, Stn. Rep. Prog. 1020, Manhattan, KS. p. 181–191.

[8]Coble, K., J. M. DeRouchey, M. D. Tokach, S. S. Dritz, R. D. Goodband, and J. C. Woodworth. 2017. Effects of distillers dried grains with solubles and added fat fed immediately before slaughter on growth performance and carcass characteristics of finishing pigs. Journal of animal science 95(1):270-278.

double-curtain sided with completely slatted concrete flooring and deep pits for manure storage. Each pen (10 × 18 ft) was equipped with adjustable gates and contained a 3-hole, dry feeder (Thorp Equipment, Inc., Thorp, WI) and a double-sided pan waterer. Feed additions were delivered and recorded using a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN).

A total of 860 finishing pigs (C48 or L42 × 327; initially 146 ± 11.1 lb BW) were used in this experiment. Pen served as the experimental unit, and there were 7 replicate pens per treatment with 23 to 25 pigs per pen. Pens were blocked by BW and location within the barn and allotted to 1 of 5 dietary treatments based on the amount of time corn DDGS were withdrawn before slaughter. Withdrawal times consisted of 76 (no DDGS), 42, 27, 15, or 0 d (no withdrawal). Pens of pigs were weighed and feed disappearance was measured on d 76, 42, 27, 15, and 0 prior to marketing to determine ADG, ADFI, and F/G.

Pigs were given *ad libitum* access to feed and water throughout the study. Diets were fed in 4 sequential phases from approximately 146 to 180, 180 to 230, 230 to 270, and 270 to 290 lb (Table 1). All pigs were fed diets containing 40% DDGS until the start of the trial. Diets with DDGS during the trial contained 35% from approximately 146 to 180 lb and 30% until the completion of the trial. Diets were corn and soybean meal-based and formulated to meet or exceed NRC[9] requirement estimates for finishing pigs. The diets contained 3.6, 3.2, 3.0, and 3.0 g standardized ileal digestible lysine per Mcal of net energy in phases 1 through 4, respectively. All diets were fed in meal form. Diets were manufactured at a commercial feed mill (Blooming Prairie, MN). Composite diet samples were sent for proximate analysis (Ward Laboratories, Kearney, NE).

According to typical farm procedures, the 4 heaviest pigs were removed 15 d prior to final barn dump, weighed, tattooed, and transported to a USDA-inspected packing plant (Tyson Fresh Meats, Waterloo, IA) for carcass data collection. Similarly, for the barn dump, all pigs were weighed and tattooed with pen identification number and pigs were then processed for data collection. Carcass measurements collected included HCW, backfat, loin depth, and percentage lean. A proprietary equation specific to the packer was utilized to calculate percentage lean. Carcass yield was calculated by dividing average HCW for the pen by the average live BW for the pen collected at the farm. On the final marketing day, two belly fat samples from each pen were collected during processing prior to carcass chilling. These samples were analyzed via gas chromatography for fatty acid analysis to calculate an iodine value (IV) according to the NRC[9] standard equation for both fatty acid as a percent of total fatty acids and as a percent of ether extract. Near infrared spectroscopy (NIR) was also conducted on duplicate samples to determine iodine value.

Economic analysis was calculated on a pen basis, both for the number of pigs that started the experiment and those that were marketed due to a naturally-occurring health challenge that increased removals for all treatments. Pigs began to demonstrate decreased performance approximately 42 d before barn dump and were later confirmed PRRS positive. Feed cost per pig was calculated by multiplying the feed cost per lb of feed by the intake during each period, totaling these values, and dividing by the number

[9]NRC. 2012. Nutrient Requirements of Swine. 11th ed. Natl. Acad. Press, Washington, DC.

of pigs started or marketed. Feed cost per lb of gain was calculated by dividing the feed cost per pig by the average weight gain per pig. Carcass gain value was calculated by multiplying carcass gain by an assumed value of $68.08 per cwt of carcass. Income over feed cost (IOFC) was calculated by subtracting the feed cost per pig from revenue per pig. Corn was valued at $3.29/bu; DDGS at $148/ton; and soybean meal at $350/ton.

Data were analyzed as a randomized complete block design for one-way ANOVA using the PROC GLIMMIX procedure of SAS (version 9.4, SAS Institute, Inc., Cary, NC) with pen considered the experimental unit, body weight as blocking factor, and treatment as fixed effect. To evaluate the effect of time, linear and quadratic contrasts were applied for the overall growth data and carcass data to evaluate the effect of duration of withdrawal across all treatments. These coefficients were generated using PROC IML to account for unevenly spaced d of withdrawal. Results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$. For intermediate periods, treatment means were separated at $P < 0.05$.

Results and Discussion

Analyzed values for DM, CP, ADF, NDF, ether extract, calcium, and phosphorus content of experimental diets (Table 2) were consistent with formulated estimates.

Growth performance for intermediate period data can be found in Table 3. Body weights on d -76, -42, -27, and -15 showed no evidence for treatment differences ($P > 0.192$). During the first withdrawal period from d -76 to -42, two treatments were evaluated: either withdrawn from DDGS at d -76 or no withdrawal. There was evidence that ADG and F/G improved ($P < 0.001$) for pigs withdrawn from DDGS diets on d -76 and no evidence that feed intake was different between treatments ($P = 0.265$). The following period evaluated -76 and -42 d withdrawal vs. no DDGS withdrawal and resulted in no evidence for differences in ADG, ADFI, or F/G ($P > 0.337$), likely due to the health challenge that occurred during this time. For d -27 to -15, there was no evidence ($P > 0.053$) that ADG and F/G differed due to treatment, yet ADFI was less ($P = 0.004$). Pigs still consuming DDGS-based diets had decreased ($P < 0.05$) feed intake compared to those pigs withdrawn on either d -42 or d -27, which were not different from each other ($P > 0.05$). Pigs that switched from DDGS diets on d -76 had intermediate feed intake to all treatments ($P > 0.05$). Finally, for d -15 to 0, ADG and ADFI were different across treatments ($P < 0.018$), yet F/G did not show evidence for differences ($P = 0.304$). Pigs withdrawn from DDGS on d -15 had increased ($P < 0.05$) ADG compared to pigs withdrawn on d -76 or those not withdrawn. Furthermore, pigs withdrawn from DDGS on d -27 had increased ($P < 0.05$) ADG compared to those pigs with no DDGS withdrawal. Average daily feed intake was decreased ($P < 0.05$) in pigs with no DDGS withdrawal compared to those withdrawn on d -42, d -27, or -15, but not different ($P > 0.05$) from those withdrawn initially on d -76. Additionally, ADFI was decreased for pigs on the -76 d withdrawal treatment compared to those withdrawn from DDGS on d -27.

Overall growth performance was evaluated using linear and quadratic contrasts to determine the effect of time (Table 4). For the overall period from d -76 to 0, as length of DDGS withdrawal increased, ADG and final BW increased (linear, $P < 0.018$), while F/G also improved (quadratic, $P = 0.022$). Average daily feed intake quadratically increased ($P = 0.030$) with increasing withdrawal time with the greatest ADFI observed in those pigs withdrawn from DDGS for 27 d before marketing.

The response detected in final BW translated to a linear increase ($P = 0.009$) in HCW, with a marginally significant response for improved carcass yield (linear, $P = 0.094$) with increasing DDGS withdrawal time. Loin depth and lean percentage did not demonstrate any evidence for treatment differences ($P > 0.132$). Backfat was linearly increased ($P = 0.030$) with increasing time of DDGS withdrawal and also marginally significant ($P = 0.084$) for a quadratic increase. Lastly, IV of belly fat was decreased (linear, $P < 0.034$) with increased withdrawal time for both methods of calculation (% of total fatty acid (FA) or % of ether extract) using FA values obtained via gas chromatography. Similarly, IV determined by NIR was also linearly decreased ($P = 0.001$) and demonstrated a marginally significant quadratic decrease ($P = 0.062$) with increasing withdrawal.

This trial occurred in a commercial finishing barn that experienced a naturally occurring health challenge during the experiment, thus impacting removals for all treatments. Although there was numerical variation, there was no evidence that withdrawal time impacted removals ($P > 0.168$). Economics were evaluated on the basis of both the number of pigs started and those marketed basis. Feed cost per pig and IOFC on a started pig basis were increased (linear, $P < 0.048$) with increasing withdrawal time. Feed cost per lb of gain did not demonstrate evidence for treatment differences ($P > 0.505$). On a marketed pig basis, feed cost per pig was increased (linear, $P = 0.001$) with increasing withdrawal time, though feed cost per lb of gain and IOFC did not have evidence for differences ($P > 0.135$). Finally, carcass gain value was increased (linear, $P = 0.001$) with increased DDGS withdrawal time.

These results are consistent with others who have evaluated feeding diets containing DDGS before slaughter that found decreased HCW[8,10] and increased IV[6,8] with longer feeding duration of DDGS. The time needed to withdraw DDGS from diets to recover negative impacts, such as hot carcass weights or fat composition, is variable between studies. Nemechek et al.[10] determined that 17 d of withdrawal was enough time to recover yield, but that belly fat required longer duration of DDGS withdrawal to turn over, which is consistent with findings by Asmus et al.[11]

Soto et al.[12] used meta-analysis to model the change in yield with increased withdrawal days and various NDF levels. This model predicted a 0.84% increase in yield with a 76 d withdrawal whereas in the present data, yield was increased by 0.60%. This model was a good prediction method to understand the impact of NDF on carcass yield, even

[10]Nemechek, J., M. D. Tokach, S. S. Dritz, R. D. Goodband, J. M. DeRouchey, and J. C. Woodworth. 2015. Effects of diet form and type on growth performance, carcass yield, and iodine value of finishing pigs. Journal of animal science 93(9):4486-4499.

[11]Asmus, M., J. DeRouchey, M. Tokach, S. Dritz, T. Houser, J. Nelssen, and R. Goodband. 2014. Effects of lowering dietary fiber before marketing on finishing pig growth performance, carcass characteristics, carcass fat quality, and intestinal weights. Journal of animal science 92(1):119-128.

[12]Soto, J.; Tokach, M. D.; Dritz, S. S.; Goncalves, M. A.; Woodworth, J. C.; DeRouchey, J. M.; and Goodband, R. D. (2017) "Regression Analysis to Predict the Impact of High Neutral Detergent Fiber Ingredients on Carcass Yield," Kansas Agricultural Experiment Station Research Reports: Vol. 3: Iss. 7. https://doi.org/10.4148/2378-5977.7495

though the current data have a longer withdrawal period than the studies included in the meta-analysis. When compared to data from shorter withdrawal periods,[13] this model predicted fairly accurately for a 28 d withdrawal, but less accurately for a 35 d withdrawal.

In conclusion, removing pigs from a DDGS-based diet for longer periods before slaughter increased ADG and F/G, resulting in increased HCW. All iodine values, whether calculated with NRC[9] equations from gas chromatography or NIR, decreased as withdrawal time increased, indicating increased saturation of the belly fat.

The economic environment for this study with moderately high-priced DDGS resulted in increased revenue for pigs withdrawn from DDGS immediately on d -76. Overall, these data suggest that the advantage in final BW and HCW observed from withdrawing DDGS before marketing may encourage producers to remove DDGS from finishing diets earlier than commonly practiced.

[13]Lerner, A. B., M. D. Tokach, J. C. Woodworth, J. M. DeRouchey, R. D. Goodband, S. S. Dritz, C. Hastad, K. Coble, E. Arkfeld, H. Calderon Cartagena, and C. Vahl. (2018). "Effects of dietary corn dried distillers grains with solubles withdrawal on finishing pigs performance and carcass characteristics," Kansas Agricultural Experiment Station Research Reports: Volume 4, Issue 9.

Table 1. Diet composition, phases 1 through 4[1]

	Dietary phase							
	DDGS				No DDGS			
Ingredient, %	1	2	3	4	1	2	3	4
Corn	55.49	60.74	60.52	62.00	78.65	81.60	82.77	82.76
Soybean meal, 46.5% crude protein	6.58	6.52	6.92	5.55	18.26	15.47	14.37	14.62
Corn DDGS	35.00	30.00	30.00	30.00	---	---	---	---
Monocalcium phosphate, 21% phosphorus	0.10	0.10	0.09	---	0.78	0.70	0.65	0.50
Limestone	1.20	1.20	1.15	1.05	0.85	0.88	0.90	0.78
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Copper sulfate	0.03	---	---	---	0.03	---	---	---
L -Lysine HCl	0.55	0.45	0.40	0.45	0.34	0.30	0.30	0.30
DL-Methionine	---	---	---	---	0.05	0.04	0.04	0.05
L-Threonine	0.07	0.05	0.04	0.08	0.08	0.08	0.10	0.12
L-Tryptophan	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Premix[2]	0.20	0.15	0.10	0.10	0.20	0.15	0.10	0.10
Phytase[3]	0.10	0.10	0.10	0.08	0.10	0.10	0.10	0.10
Sodium metabisulfite	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Total	100	100	100	100	100	100	100	100
Calculated analysis								
Standardized ileal digestible (SID) amino acids, %								
Lysine:Net energy, g/Mcal	3.56	3.15	3.04	3.04	3.56	3.15	3.04	3.06
Lysine	0.88	0.78	0.76	0.76	0.89	0.79	0.77	0.77
Isoleucine:lysine	60	64	67	64	59	61	60	61
Leucine:lysine	183	194	203	197	139	148	150	149
Methionine:lysine	32	34	36	35	31	32	32	34
Methionine and cystine:lysine	60	64	67	65	56	59	60	61
Threonine:lysine	60.7	63.0	64.9	67.2	60.4	62.9	65.1	67.6
Tryptophan:lysine	17.8	19.3	19.7	19.2	19.3	20.3	19.6	19.7
Valine:lysine	75	80	84	80	67	70	70	70
Total lysine, %	1.05	0.94	0.91	0.91	1.00	0.90	0.87	0.88
Net energy, kcal/lb	1,120	1,128	1,128	1,135	1,134	1,143	1,146	1,149
Crude protein, %	17.8	16.7	16.9	16.4	15.4	14.3	13.9	14.0
Calcium, %	0.54	0.53	0.51	0.45	0.54	0.53	0.53	0.45
Phosphorus, %	0.42	0.40	0.40	0.38	0.49	0.47	0.45	0.42
Available phosphorus, %	0.21	0.19	0.19	0.17	0.22	0.20	0.19	0.16

[1]Diets were fed in four sequential phases from approximately 146 to 180, 180 to 230, 230 to 270, and 270 until 290 lb.
[2]Provided 700,000 IU vitamin A from vitamin A acetate; 200,000 IU vitamin D from vitamin D_3; 3,650 IU vitamin E from dl-α-tocopheryl acetate; 400 mg menadione from menadione nicotinamide bisulfite; 3.6 mg B_{12} from cyanocobalamin; 6,800 mg niacin from niacinamide; 3,000 pantothenic acid from d-calcium panthothenate; 900 mg riboflavin from crystalline riboflavin; 1.4 g Cu from copper sulfate; 72.7 mg Ca from calcium iodate; 14 mg Fe from ferrous sulfate; 1.5 g Mn from manganese sulfate; 54.5 mg Se from sodium selenite; and 14 g Zn from zinc sulfate per lb of premix.
[3]Ronozyme HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided 1,102,300 phytase units/kg of product with an assumed release of 0.10% available P.

Table 2. Analyzed diet composition, phases 3 through 6[1]

	Dietary phase							
	No DDGS				DDGS			
Item, %	3	4	5	6	3	4	5	6
Dry matter	87.5	88.2	87.4	87.3	88.7	88.5	88.4	88.9
Crude protein	14.8	12.8	12.5	12.6	16.0	16.1	16.6	16.8
Acid detergent fiber	3.0	2.9	3.1	3.5	6.5	6.7	6.2	5.4
Neutral detergent fiber	5.7	6.3	6.5	6.1	12.9	12.1	12.6	12.0
Calcium	0.71	0.93	0.69	0.65	0.74	0.65	0.69	0.37
Phosphorus	0.51	0.45	0.46	0.40	0.59	0.50	0.54	0.51
Ether extract	2.70	2.70	3.00	2.90	4.80	4.30	4.20	4.40

[1]Diets were fed in four sequential phases from approximately 146 to 180, 180 to 230, 230 to 270, and 270 until 290 lb.

Table 3. Effects of DDGS withdrawal on finishing pig performance within phase[1,2]

	DDGS diet withdrawal before market, d						
Item[3]	76	42	27	15	0	SEM	Probability, P =
BW, lb							
d -76	145.7	---	---	---	146.0	3.91-4.40	0.906
d -42	225.1	220.4	---	---	220.3	4.51-4.99	0.278
d -27	250.1	243.9	244.8	---	244.0	4.77-5.06	0.192
d -15	267.6	264.3	264.4	260.7	261.0	5.08	0.451
d -76 to -42							
n (pens)	7	---	---	---	28		
ADG, lb	2.34[a]	---	---	---	2.17[b]	0.043-0.051	0.001
ADFI, lb	5.97	---	---	---	5.88	0.191-0.202	0.265
F/G	2.55[b]	---	---	---	2.71[a]	0.041-0.047	0.001
d -42 to -27							
n (pens)	7	7	---	---	21		
ADG, lb	1.66	1.56	---	---	1.59	0.044-0.073	0.565
ADFI, lb	5.96	5.94	---	---	6.14	0.249-0.276	0.374
F/G	3.57	3.92	---	---	3.90	0.136-0.210	0.337
d -27 to -15							
n (pens)	7	7	7	---	14		
ADG, lb	1.53	1.67	1.57	---	1.40	0.072-0.093	0.053
ADFI, lb	5.80[a,b]	6.13[a]	6.04[a]	---	5.36[b]	0.138-0.186	0.004
F/G	3.84	3.71	3.89	---	3.95	0.170-0.223	0.825
d -15 to 0							
n (pens)	7	7	7	7	7		
ADG, lb	2.07[b,c]	2.13[a,b,c]	2.20[a,b]	2.27[a]	1.97[c]	0.063	0.018
ADFI, lb	7.13[b,c]	7.34[a,b]	7.59[a]	7.44[a,b]	6.86[c]	0.147	0.002
F/G	3.46	3.45	3.46	3.28	3.51	0.107	0.304

[abc]Means lacking common superscripts differ ($P < 0.05$).

[1]A total of 860 finishing pigs (initially 146 ± 11.1 lb) were used in a 76-d experiment to evaluate the effects of removing corn dried distillers grains with solubles (DDGS) from diets at increasing intervals prior to harvest.

[2]All pigs were fed diets containing 40% DDGS until the start of the trial. Diets with DDGS during the trial contained 35% from approximately 146 to 180 lb and 30% until the completion of the trial.

[3]ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency. BW = body weight.

Table 4. Effects of dried distillers grains with solubles (DDGS) withdrawal on overall growth performance, carcass characteristics, and economics of finishing pigs [1,2,3]

	DDGS diet withdrawal before market, d						Probability, *P* =	
Item[4]	76	42	27	15	0	SEM	Linear	Quadratic
Growth performance								
d -76 to 0								
ADG, lb	2.02	1.94	1.97	1.95	1.90	0.028	0.002	0.973
ADFI, lb	6.14	6.17	6.28	6.10	6.02	0.156	0.251	0.030
F/G	3.03	3.18	3.19	3.13	3.17	0.062	0.003	0.022
Final BW, lb	295.0	290.3	290.9	287.8	283.6	4.89	0.018	0.573
Removals, %	5.0	6.2	2.5	2.5	3.6	1.31-2.44	0.168	0.872
Carcass characteristics								
HCW, lb	218.6	215.5	214.4	211.9	209.1	4.03	0.009	0.554
Yield, %	73.6	73.6	73.3	73.0	73.0	4.13	0.094	0.615
Loin depth, in.[3]	2.83	2.83	2.83	2.85	2.86	0.028	0.335	0.532
Backfat, in.[3]	0.51	0.50	0.52	0.50	0.48	0.026	0.030	0.084
Lean, %[3]	57.1	57.2	57.1	57.3	57.4	0.20	0.132	0.232
Iodine value								
GC,[5] % of FA	65.2	66.5	67.0	65.8	69.4	1.08	0.030	0.364
GC,[6] % of EE	68.1	69.5	70.0	68.7	72.6	1.13	0.031	0.365
NIR[7]	66.8	68.2	69.9	69.5	74.0	0.99	0.001	0.062
Economic analysis								
Started pig basis								
Feed cost/pig, $	38.48	36.25	37.41	35.61	35.05	0.873	0.001	0.857
Feed cost/lb gain, $	0.26	0.25	0.26	0.25	0.25	0.006	0.505	0.807
IOFC, $	35.90	35.49	34.05	34.22	32.91	1.104	0.048	0.586

continued

Table 4. Effects of dried distillers grains with solubles (DDGS) withdrawal on overall growth performance, carcass characteristics, and economics of finishing pigs [1,2,3]

	DDGS diet withdrawal before market, d						Probability, P =	
Item[4]	76	42	27	15	0	SEM	Linear	Quadratic
Marketed pig basis								
Feed cost/pig, $	40.97	39.12	38.60	36.73	36.76	1.187	0.001	0.905
Feed cost/lb gain, $	0.27	0.27	0.27	0.26	0.27	0.007	0.135	0.754
IOFC, $	33.42	32.63	32.87	33.11	31.19	1.314	0.335	0.621
Carcass gain value, $	74.39	71.74	71.47	69.83	67.95	1.224	0.001	0.508

[1]A total of 860 finishing pigs (initially 146 ± 11.1 lb) were used in a 76-d experiment to evaluate the effects of removing corn DDGS from diets at varying intervals prior to harvest.
[2]Pigs were fed diets containing 40% DDGS until the start of the trial. Diets with DDGS during the trial contained 35% from approximately 146 to 180 lb and 30% until the completion of the trial.
[3]Corn was valued at $3.29/bu; DDGS at $148/ton; and soybean meal at $350.40/ton.
[4]ADG = Average daily gain. ADFI = average daily feed intake. F/G = feed efficiency. BW = body weight. HCW = hot carcass weight. IOFC = income over feed cost.
[5]Fatty acid (FA) values obtained via gas chromatography (GC). Iodine value was calculated according to the NRC (2012) equation and consider FA as a percent of total FA: Iodine value = [% C16:1] × 0.9502 + [% C18:1] × 0.8598 + [% C18:2] × 1.7315 + [% C18:3] × 2.6152 + [% C20:1] × 0.7852 + [% C22:1] × 0.7225 + [% C22:5] × 3.6974 + [% C22:6] × 4.4632.
[6]FA values obtained via gas chromatography. Iodine value was calculated according to the NRC (2012) equation and consider FA as a percent of ether extract (EE): Iodine value = [% C16:1] × 0.9976 + [% C18:1] × 0.8985 + [% C18:2] × 1.8099 + [% C18:3] × 2.7345 + [% C20:1] × 0.8173 + [% C22:1] × 0.7496 + [% C22:5] × 3.8395 + [% C22:6] × 4.6358.
[7]Iodine values obtained via near infrared spectroscopy.