Effects of corn distillers dried grains with solubles in finishing diets on pig growth performance and carcass yield with two different marketing strategies

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ABSTRACT: Feeding diets high in corn distillers dried grains with solubles (**DDGS**) before market can negatively impact carcass yield, hot carcass weight (**HCW**), and belly fat iodine value (**IV**). Two experiments were conducted to evaluate the effects of switching from DDGS-based to corn-soybean meal (**CSBM**)-based diets at increasing intervals (withdrawal periods) before harvest on finishing pig performance and carcass characteristics. Diets in both experiments contained either 0% or 30% DDGS and were balanced for net energy (**NE**). In Exp. 1, 985 pigs (initially 99.6 kg body weight [**BW**]) were used with 12 pens per treatment. The four treatments were increasing DDGS withdrawal periods: 28, 21, 14, or 0 d (no dietary switch) before marketing. All pens were marketed by removing the 17% heaviest pigs 21 d before slaughter and the remaining 83% all slaughtered 21 d later. Overall, there was no evidence for treatment differences on final BW, average daily feed intake, or feed efficiency (**G:F;** *P* > 0.10); however, average daily gain (**ADG**) increased (linear, *P* = 0.022) and belly fat IV decreased (linear, *P* = 0.001) the longer pigs were fed CSBM diets. There was no evidence for differences for HCW (*P* > 0.10); however, carcass yield increased (linear, *P* = 0.001) with increasing time following the switch to CSBM. Backfat depth decreased and percentage lean increased as CSBM feeding time increased (quadratic; *P* < 0.05). In Exp. 2, 1,158 pigs (initially 105 kg BW) were used in a 35-d study. There were 15 pens per treatment and four treatments of increasing DDGS withdrawal periods: 35, 28, 14, or 0 d (no dietary switch). All pens were marketed by removing the 15% heaviest pigs on day 28, the 28% heaviest pigs on day 14, and a final marketing of approximately 57% of starting barn inventory. There was no evidence that final BW, ADG, G:F, or HCW differed among dietary treatments (*P* > 0.10). Average daily feed intake and carcass yield increased and belly fat IV decreased (*P* < 0.050); the longer pigs were fed CSBM. In conclusion, growth performance was minimally impacted following dietary switch from DDGS- to CSBM-based diets, possibly due to similar dietary NE. For carcass yield and belly fat IV, the optimal time to make a dietary switch from high to low fiber appears to be linear in nature and at least 28 d before marketing.

Key words: carcass characteristics, carcass fatty acids, DDGS, finishing pigs, growth

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INTRODUCTION

Corn distillers dried grains with soluble (**DDGS**) is a byproduct of the ethanol industry. Information regarding use of DDGS in growing-finishing diets is widely available, and generally concludes that DDGS may be included in diets at up to 30% before adverse effects in growth performance are observed (Stein and Shurson, 2009); however, a majority of these data was collected prior to 2009, where oil content was higher than that of current DDGS. DDGS are high in neutral detergent fiber (**NDF**), and thus may negatively affect carcass yield and HCWs (Coble et al., 2017). Additionally, DDGS contain relatively high concentrations of unsaturated fatty acids which can lead to increased pork fat iodine value (**IV**; Whitney et al., 2006). Decreased carcass yield and poor fat quality can result in economic ramifications when marketing pigs.

To overcome the negative effects of feeding DDGS (or high NDF diets) before market, pigs may be switched from diets containing high NDF to corn–soybean meal diets in the final days or weeks of the finishing period. Coble et al. (2017) reported that a 5 or 9 d withdrawal period (time of dietary switch from DDGS- to corn–soybean meal-based diets) of DDGS and wheat middlings recovered yield and HCW reductions. Asmus et al. (2014) fed finishing pig diets containing both DDGS and wheat middlings and changed the NDF levels in finishing diets either 43 or 67 d before slaughter, concluding that short CSBM feeding durations could recover yield losses, but longer periods were needed to restore carcass fat IV.

Often in commercial pork production, groups of pigs that reach market weight requirements ahead of their cohorts are sold prior to the final barn marketing, rather than selling all pens of pigs at one time. Strategies that utilize multiple marketing events are effective in reducing market weight variation and improving the growth performance of the remaining pigs (Woodworth et al., 2000; DeDecker et al., 2005; DeDecker, 2006). Due to seasonal changes in pig growth, pork prices, and space availability within a production system, multiple marketing strategies may be utilized differently throughout the year to maximize profitability. For example, increased temperatures can result in poor feed intake, feed conversion, and growth rate (White et al., 2008). Therefore, pigs often grow slower during the summer than winter. To account for these seasonal differences in growth rates, many swine producers utilize more marketing events during cool months as pigs reach market weight faster than during warm months.

Therefore, it is important to understand the appropriate feeding duration of DDGS before harvest in order to maximize profitability while mitigating reductions in performance, carcass yield, and pork quality. The objective of these experiments was to determine the appropriate time to switch from diets containing DDGS to those containing only corn and soybean meal before marketing in finishing pig diets in two different marketing scenarios.

MATERIALS AND METHODS

General

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. Both studies were conducted at a commercial research facility owned and operated by New Fashion Pork (Jackson, MN). The barns were tunnel-ventilated with completely slatted concrete flooring and deep pits for manure storage. Each pen (2.4 × 5.5 m, Exp. 1; 2.4 × 5.8 m, Exp. 2) was equipped with adjustable gates (initially providing ~0.70 m^2 per pig) and a three-hole, dry feeder (Thorp Equipment, Inc., Thorp, WI) and a pan waterer. Feed and water were offered ad libitum and feed additions were delivered and recorded using a robotic feeding system (FeedPro, Feedlogic Corp., Willmar, MN). In each trial, two different marketing strategies were employed representative of marketing techniques used in warm and cold months. The first experiment had one marketing event then sold all pigs 21 d later, and the second experiment had two marketing events before the remaining pigs were sold.

Experiment 1

For Exp. 1, 985 finishing pigs (initially 100 ± 2.5 kg BW; PIC TR4 × [Fast LW × PIC L02] were used in a 28-d experiment. Pen served as the experimental unit with 12 pens per treatment and 19–21 pigs per pen balanced within block. There were four treatments increasing DDGS withdrawal periods: 28, 21, 14, or 0 d (no dietary switch). Regardless of treatment, pens of pigs were marketed with one marketing event prior to final barn marketing (day 0), which mimics a seasonal marketing structure commonly implemented during warm months when pigs are growing slower. All pens were marketed by removing the 17% heaviest pigs on d 21 prior to market resulting in a final barn marketing of approximately 83% of starting pen inventory. Pens of pigs were weighed every 7 d, with individual weights collected at marketing. Growth performance includes pigs sold prior to final marketing events.

Pigs were provided ad libitum access to feed and water. Prior to the experiment, all pigs were fed diets containing 30% DDGS starting at 34 kg BW. Diets were either CSBM-based or contained 30% DDGS (Table 1). All diets were formulated to meet or exceed NRC (2012) nutrient requirement estimates. Experimental diets contained 0.77% standardized ileal digestible (**SID**) lysine and were balanced for net energy (**NE**). Nutrient values for all ingredients and standardized ileal digestibility coefficients of amino acids used in diet formulation were derived from NRC (2012). Net energy of DDGS was calculated using an assumed oil content (7.5%) based on an equation by Nitikanchana et al. (2013). Proximate analysis completed on DDGS samples taken during the experiment resulted in 88.5% dry matter, 27.7% crude protein, 5.8% crude fiber, and 6.8% ether extract. Feed was manufactured at a commercial mill (Worthington, MN). Composite diet samples were obtained and stored at −20 °C until analysis. Samples were analyzed (Ward Laboratories, Inc., Kearney, NE) for DM (method 935.29; AOAC International, 1990), CP (method 990.03; AOAC International, 1990), Ca (method 985.01; AOAC International, 1990), P (method 985.01; AOAC International, 1990), ADF and NDF (Van Soest et al., 1991), and ether extract (method 920.39; AOAC International, 1990).

Pigs to be harvested were identified with tattoos indicating pen of origin and RFID ear tags for individual identification. Pigs were then transported to a USDA-inspected packing plant (Triumph Foods, St. Joseph, MO) for processing and carcass data collection. Carcass measurements collected on pigs

Table 1. Diet composition (as-fed basis), Exps. 1 and 2[1]

Ingredient, %	Corn-soybean meal	DDGS
Corn	80.86	61.15
Soybean meal, 46.5% crude protein	15.17	4.61
Corn distillers dried grains with solubles	—	30.00
Choice white grease	1.65	2.00
Calcium carbonate	0.83	1.10
Monocalcium phosphate, 21% P	0.43	—
Sodium chloride	0.45	0.35
L-Lysine-HCl	0.28	0.50
DL-Methionine	0.07	—
L-Threonine	0.11	0.11
L-Tryptophan	0.03	0.06
Phytase[2]	0.03	0.03
Vitamin and mineral premix[3]	0.10	0.10
Total	100.00	100.00
Calculated analysis		
Standardized ileal digestible (SID) amino acids[4], %		
Lysine	0.77	0.77
Isoleucine:lysine	62	61
Leucine:lysine	150	191
Methionine:lysine	36	34
Methionine and cysteine:lysine	64	64
Threonine:lysine	68	68
Tryptophan:lysine	21	21
Valine:lysine	71	77
Total lysine, %	0.87	0.92
Metabolizable energy, kcal/kg	3,402	3,366
Net energy, kcal/kg	2,612	2,612
SID lysine:net energy, g/Mcal	2.95	2.95
Crude protein, %	14.3	16.3
Calcium, %	0.46	0.49
Phosphorus, %	0.41	0.41
Sodium, %	0.21	0.22
Standardized total tract digestible P, %	0.30	0.31

[1]Diets were fed from approximately 100 to 132 kg in Exp. 1 and 105 to 132 kg in Exp. 2 and based on NRC nutrient values.

[2]Ronozyme HiPhos 2500 (DSM Nutritional Products, Inc., Parsippany, NJ) provided 751 FYT/kg of diet with an assumed release of 0.12% P.

[3]Provided 2,616,860 IU vitamin A from vitamin A acetate, 266,666 vitamin D3 from cholecalciferol, 523,332 IU vitamin D from 25-hydryoxycholecalciferol, 16,169 mcg vitamin B12 from vitamin B12, 5,880 mg riboflavin, 17,637 mg niacin from nicotinic acid, 11,759 mg d-pantothenic acid from dl-pantothenic acid, 1,764 mg menadione from menadione sodium bisulfate complex, 661 ppm Se from sodium selenite, 33,069 ppm Cu from tri-basic copper chloride, 111,700 ppm Fe from ferrous sulfate, 198,414 ppm Zn from zinc hydroxychloride, 55,115 ppm Mn from manganese hydroxychloride, and 558 ppm I from ethylenediamine dihydriodide per kg of premix.

[4]Calculated using NRC (2012) digestibility coefficients.

from all marketing events included HCW, backfat, loin depth, and lean percentage. Carcass yield was calculated by dividing the individual pig's live weight at the farm by the individual pig's HCW. A proprietary equation specific to the packer was utilized to calculate percentage lean. On the final barn marketing days, belly fat samples anterior to the manubrium were collected from four barrows per pen (closest to the mean pen weight). Samples were analyzed by near-infrared spectroscopy (Triumph Foods) for fat IV.

Experiment 2

In Exp. 2, 1,158 finishing pigs (initially 105 ± 2.0 kg BW) were used in a 35-d experiment. Pen served as the experimental unit, with 15 pens per treatment and 17–21 pigs per pen balanced within block. Similar to Exp. 1, there were four treatments of increasing DDGS withdrawal periods: 35, 28, 14, or 0 d (no dietary switch). All pens were marketed according to a typical winter marketing strategy for this production system with two marketing events prior to the final barn marketing. During the winter months pigs generally grow faster than summer months, thus reaching the ideal market weight faster. Hence, pigs are generally marketed in multiple marketing events during the winter. All pens were marketed by removing the 15% heaviest pigs on day 28 prior to market, the next 28% heaviest pigs on d 14 prior to market, and a final barn marketing of approximately 57% of starting barn inventory. Pigs were weighed every 7 d. Experimental diets and carcass collection procedures were identical to Exp. 1.

Statistical Analysis

Data were analyzed as a completely randomized design with the fixed effects of treatment using the PROC GLIMMIX procedure of SAS (version 9.4, SAS Institute, Inc., Cary, NC). Pen was the experimental unit for growth and carcass data. To evaluate growth data, each intermediate period was analyzed with an individual analysis of variance model to evaluate the fixed effect of treatment at that point in time. For example, during day 28 to 21 before marketing in Exp. 1, the only treatment to be applied was the 28-d dietary switch; therefore, these pens are compared with the remaining pens that were yet to be assigned to treatment and switched to CSBM diets. Individual carcass data were analyzed with a mixed model using PROC GLIMMIX to account for the correlation among pigs sharing the same pen (experimental unit) with a repeated measures design. To evaluate the effect of time, linear and quadratic contrasts were applied for the overall growth and carcass data to evaluate the effect of duration following dietary switch from DDGS to CSBM across all treatments. The PROC IML procedure was utilized to generate linear and quadratic coefficients for unevenly spaced time between dietary switches. In Exp. 1, one pen was removed from the data set due to incorrect feed provided to the pen during the final period. Residual outliers within the carcass data were removed if plant data provided evidence indicating a defect where the carcass was skinned. In addition, two carcasses in Exp. 2 were removed because their residual values were notably increased compared with the overall population. No carcasses were removed for Exp 1. Results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

RESULTS

Analyzed diet composition was similar to anticipated values for all proximate analysis components (Table 2). Further, DDGS diets contained increased NDF content compared with CSBM diets as expected. Levels of NDF were similar to other literature (12–13%) when diets included 30% DDGS (Lerner et al., 2019), yet lower than experiments that included both 30% DDGS and 19% wheat middlings (Asmus et al., 2014; Coble et al., 2018).

Experiment 1

There was no evidence ($P > 0.10$) for treatment differences in BW throughout the trial (Table 3). During day 28 to 21 before final barn marketing, there was no evidence ($P > 0.10$) for treatment differences in average daily gain

Table 2. Diet analysis, Exp. 1 and 2[1]

Item, %	Corn-soybean meal	DDGS
Dry matter	88.3	89.1
Crude protein	14.3	16.6
Acid detergent fiber	4.6	5.8
Neutral detergent fiber	8.6	12.8
Calcium	0.55	0.63
Phosphorus	0.40	0.48
Ether extract	4.4	5.7

[1]Diets were fed from approximately 100–132 kg in Exp. 1 and 105–132 kg in Exp. 2.

Table 3. Effects of DDGS withdrawal periods on weekly finishing pig performance, Exp. 1[1,2,3]

	DDGS withdrawal period, day before marketing				
Item[4]	28	21	14	0	Probability, P
BW[5], kg					
day 28	99.6	—	—	99.5	0.961
	0.73	—	—	0.42	
day 21	107.7	107.3	—	107.4	0.947
	0.84	0.84	—	0.59	
day 14	113.4	113.4	112.2	112.2	0.640
	0.93	0.93	0.93	0.93	
day 7	119.9	119.3	118.7	118.7	0.731
	0.92	0.92	0.92	0.92	
Final BW	127.1	126.5	125.6	125.8	—[6]
	0.941	0.941	0.982	0.941	
day 28 to 21					
n (pens):	12	—	—	36	—
ADG, kg	1.16	—	—	1.12	0.198
	0.029	—	—	0.017	
ADFI, kg	3.02	—	—	3.02	0.981
	0.050	—	—	0.029	
G:F	0.385	—	—	0.372	0.199
	0.0090	—	—	0.0052	
day 21 to 14					
n (pens):	12	12	—	24	—
ADG, kg	1.15[a]	1.15[a]	—	1.04[b]	0.033
	0.039	0.039	—	0.027	
ADFI, kg	2.90	2.80	—	2.78	0.364
	0.065	0.065	—	0.046	
G:F	0.398[ab]	0.409[a]	—	0.373[b]	0.016
	0.0104	0.0104	—	0.0073	
day 14 to 7					
n (pens):	12	12	12	12	—
ADG, kg	0.92	0.85	0.93	0.92	0.272
	0.031	0.031	0.031	0.031	
ADFI, kg	2.89[a]	2.86[a]	2.76[a,b]	2.66[b]	0.027
	0.057	0.057	0.057	0.057	
G:F	0.319[a,b]	0.299[b]	0.338[a]	0.348[a]	0.017
	0.0113	0.0113	0.0113	0.0113	
day 7 to 0					
ADG, kg	1.02	1.02	0.96	1.03	0.259
	0.026	0.026	0.027	0.026	
ADFI, kg	3.02	3.03	3.00	2.93	0.303
	0.038	0.038	0.040	0.038	
G:F	0.338	0.337	0.321	0.352	0.135
	0.0088	0.088	0.0092	0.0088	

[ab]Means within a row with different superscripts differ, $P < 0.05$.

[1]A total of 985 finishing pigs (initially 99.6 ± 2.5 kg BW) were used in a 28-d experiment to evaluate the effects of DDGS withdrawal periods.

[2] Pigs were fed diets containing 30% DDGS until the start of the trial. Diets with DDGS during the trial also contained 30%..

[3]Pens of pigs were marketed according to a typical summer marketing strategy with one top prior to final barn marketing. All pens were marketed by removing the 17% heaviest pigs 21 before final marketing resulting in a final barn marketing of approximately 83% of starting barn inventory.

[4]Standard error of the means are reported below the treatment means.

[5]BW = body weight.

[6]Linear, P =0.328; quadratic, P = 0.476.

(**ADG**), average daily feed intake (**ADFI**), or feed efficiency (**G:F**). The following period, day 21 to 14 before market, evaluated three treatments: switching to CSBM on day 28 before market, day 21 before market, or not yet switched. There was no evidence (P = 0.364) that ADFI was different between treatments. ADG was increased ($P < 0.05$) for pigs switched to CSBM diets compared with pens of pigs remaining on diets containing DDGS. Feed efficiency was improved ($P < 0.05$) for pigs switched to CSBM diets 21 d before marketing compared to pigs with no dietary switch, while pigs switched on d 28 before market had intermediate G:F ($P > 0.05$). During daay 14 to 7 before market, ADG did not result in evidence for differences across treatments ($P > 0.10$). Feed intake was increased ($P < 0.05$) for pens switched to CSBM on day 28 or 21 before market compared with pens that remained on DDGS, yet ADFI was not different from each other ($P > 0.05$). Pens of pigs switched on day 14 before market had intermediate ($P > 0.05$) ADFI compared with the other treatments. Feed efficiency was not different ($P > 0.05$) between the day 14 dietary switch and no dietary switch treatments, but their G:F was improved ($P < 0.05$) compared with the 21-d withdrawal period treatment. Pens switched from DDGS to CSBM on 28 d before market had intermediate G:F ($P > 0.05$) compared with all other treatments. There was no evidence ($P > 0.10$) that ADG, ADFI, or G:F differed for the last 7 d of the trial.

For the first marketing event on 21 d before market (Table 4), there was no evidence ($P > 0.10$) for treatment differences in HCW, backfat, loin depth, or lean percentage. Carcass yield tended ($P = 0.089$) to be increased for pigs switched from DDGS to CSBM on d 28 before market (or 7 d before the first marketing event) compared to those still consuming DDGS. The remaining pigs were marketed at the end of the trial (d 0), representing the final barn marketing in which all treatments

Table 4. Effects of DDGS withdrawal periods on carcass characteristics for individual marketing events, Exp. 1[1,2,3]

	DDGS withdrawal period, d before marketing				Probability, P =		
Item[4]	28	21	14	0	Trt	Linear	Quadratic
First marketing (day 21 prior to market)							
HCW, kg	89.2	—	—	88.1	0.401	—	—
	1.09			0.62			
Carcass yield, %	73.9	—	—	73.3	0.089	—	—
	0.30			0.17			
Backfat, mm[5]	15.1	—	—	15.7	0.314	—	—
	0.45			0.26			
Loin depth, mm[5]	61.1	—	—	60.4	0.265	—	—
	0.55			0.30			
Lean, %[5]	54.9	—	—	54.5	0.252	—	—
	0.25			0.14			
Final marketing							
HCW, kg	96.6	96.4	95.7	94.6	—	0.061	0.812
	0.80	0.80	0.84	0.80			
Carcass yield, %	76.2	76.0	76.2	75.0	—	0.001	0.055
	0.20	0.20	0.21	0.21			
Backfat, mm[5]	14.8	15.0	15.5	15.1	—	0.225	0.073
	0.21	0.21	0.22	0.21			
Loin depth, mm[5]	63.8	63.1	63.4	62.8	—	0.072	0.631
	0.32	0.33	0.34	0.33			
Lean, %[5]	54.9	54.7	54.6	54.6	—	0.084	0.111
	0.11	0.11	0.12	0.11			
Iodine value[6]	71.0	71.3	71.3	73.0	—	0.001	0.069
	0.26	0.26	0.26	0.25			

[1]A total of 985 finishing pigs (initially 99.6 ± 2.5 kg BW) were used in a 28-d experiment to evaluate the effects of DDGS withdrawal periods.

[2]Pigs were fed diets containing 30% DDGS until the start of the trial. Diets with DDGS during the trial also contained 30%.

[3]Pens of pigs were topped according to a typical summer marketing strategy with one top prior to final barn final barn marketing. All pens were topped by removing the 17% heaviest pigs 21 days before marketing resulting in a final barn marketing of approximately 83% of starting barn inventory.

[4] Standard error of the means are reported below the treatment means.

[5]Hot carcass weight was used as a covariate.

[6]Belly fat.

were evaluated. For this final marketing event, there was a marginally significant (linear, P = 0.061) response where HCW increased with increasing time after dietary switch from DDGS to CSBM. Furthermore, carcass yield was increased (linear, P = 0.001) as time of dietary switch before market increased. Backfat tended to increase (quadratic, P = 0.073) with increased time after dietary switch. Loin depth and percentage lean tended to increase (linear, P < 0.084) with increasing duration before market after dietary switch. Lastly, belly fat IV decreased (linear, P = 0.001) with increased time after switching from DDGS to CSBM.

For overall data, there was no evidence (P > 0.112) for dietary treatment effects on final BW, ADFI, or G:F (Table 5). However, ADG increased (linear, P = 0.022) as time after switching from DDGS to CSBM increased before marketing. There was no evidence (P > 0.106) for treatment differences in HCW or loin depth. Carcass yield was increased (linear, P < 0.001) with increasing withdrawal period. Backfat decreased (quadratic; P = 0.019) and percentage lean increased (quadratic; P = 0.033) as withdrawal period increased.

Experiment 2

There was no evidence that initial or subsequent BW were different (P > 0.535) between treatments (Table 6). During day 35 to 28 prior to market, pigs switched from DDGS-based to CSBM diets on day 35 prior to market had increased (P = 0.007) feed intake and tended (P = 0.066) to have increased ADG compared with pigs still consuming DDGS. There was no evidence (P = 0.873) for treatment differences in G:F during this period. From day 28 to 21 before market, there was no evidence (P > 0.135) for differences across treatments for ADG or ADFI. Pigs switched from DDGS to CSBM on day 35 before market had poorer (P < 0.05) G:F compared with pigs either switched on day 28 prior to market or not yet switched, which were not different from each other (P > 0.05). The subsequent period (day 21 to 14 before market) evaluated the same three treatments and resulted in no evidence for treatment differences for G:F (P = 0.317). ADG was similar (P > 0.05) between the treatments that were switched from DDGS to CSBM on either day 35 or day 28 before market, and both treatments

Table 5. Effects of DDGS withdrawal periods on overall growth performance and carcass characteristics, Exp. 1[1,2,3]

	DDGS withdrawal period, day before marketing				Probability, P	
Item[4]	28	21	14	0	Linear	Quadratic
Growth performance						
ADG, kg	1.07	1.04	1.02	1.02	0.022	0.202
	0.014	0.014	0.014	0.014		
ADFI, kg	2.96	2.92	2.90	2.87	0.112	0.729
	0.041	0.041	0.043	0.041		
G:F	0.361	0.357	0.354	0.357	0.479	0.248
	0.0037	0.0037	0.0039	0.0037		
Final BW, kg	127.1	126.5	125.6	125.8	0.328	0.476
	0.941	0.941	0.982	0.941		
Carcass characteristics						
HCW, kg	95.3	94.6	94.1	93.7	0.166	0.702
	0.81	080	0.83	0.81		
Carcass yield, %	75.8	75.5	75.6	74.7	0.001	0.377
	0.18	0.18	0.19	0.18		
Backfat, mm[5]	14.8	15.2	15.6	15.1	0.430	0.019
	0.19	0.19	0.20	0.20		
Loin depth, mm[5]	63.3	62.4	62.9	62.5	0.106	0.388
	0.27	0.27	0.28	0.27		
Lean, %[5]	54.9	54.6	54.5	54.7	0.214	0.033
	0.11	0.11	0.11	0.11		

[1]A total of 985 finishing pigs (initially 99 ± 2.5 kg BW) were used in a 28-d experiment to evaluate the effects of DDGS withdrawal periods.

[2]Pigs were fed diets containing 30% DDGS until the start of the trial. Diets with DDGS during the trial also contained 30%.

[3]Pens of pigs were topped according to a typical summer marketing strategy with one top prior to final barn marketing. All pens were topped by removing the 17% heaviest pigs 21 days before final marketing, resulting in a final barn marketing of approximately 83% of starting barn inventor.

[4]Standard error of the means are reported below the treatment means.

[5] HCW was used as a covariate.

Table 6. Effects of DDGS withdrawal periods on weekly finishing pig performance, Exp. 2[1,2,3]

	DDGS withdrawal period, d before marketing				
Item[4]	35	28	14	0	Probability, *P*
BW, kg					
day 35	105.2	—	—	105.2	0.978
	0.51	—	—	0.30	
day 28	112.6	112.3	—	112.3	0.912
	0.56	0.56	—	0.40	
day 21	117.6	118.2	—	118.3	0.646
	0.65	0.65	—	0.46	
day 14	125.0	125.3	125.0	125.2	0.989
	0.65	0.65	0.65	0.65	
day 7	128.2	128.0	128.9	128.3	0.817
	0.75	0.75	0.75	0.75	
Final BW	135.8	134.9	136.6	136.0	—[5]
	0.81	0.81	0.81	0.81	
day 35 to 28					
n (pens):	15	—	—	45	
ADG, kg	1.06	—	—	1.01	0.066
	0.025	—	—	0.014	
ADFI, kg	3.09	—	—	2.96	0.007
	0.041	—	—	0.024	
G:F	0.344	—	—	0.343	0.873
	0.0060	—	—	0.0035	
day 28 to 21					
n (pens):	15	15	—	30	
ADG, kg	1.05	1.10	—	1.11	0.135
	0.027	0.027	—	0.019	
ADFI, kg	3.19	3.17	—	3.10	0.164
	0.040	0.040	—	0.029	
G:F	0.328[a]	0.348[b]	—	0.359[b]	0.008
	0.0078	0.0078	—	0.0056	
day 21 to 14					
ADG, kg	1.03[a]	1.02[a]	—	0.96[b]	0.004
	0.021	0.021	—	0.015	
ADFI, kg	3.22[ab]	3.24[a]	—	3.11[b]	0.034
	0.044	0.044	—	0.031	
G:F	0.322	0.315	—	0.309	0.371
	0.0071	0.0071	—	0.0051	
day 14 to 7					
n (pens):	15	15	15	15	
ADG, kg	1.03	1.04	1.10	1.00	0.094
	0.028	0.028	0.028	0.028	
ADFI, kg	3.20[a]	3.20[a]	3.30[a]	3.04[b]	0.001
	0.043	0.043	0.043	0.043	
G:F	0.322	0.326	0.334	0.329	0.862
	0.0010	0.0010	0.0010	0.0010	
d 7 to 0					
ADG, kg	1.10[a]	0.99[b]	1.10[a]	1.11[a]	0.066
	0.034	0.034	0.034	0.034	
ADFI, kg	3.52[a]	3.42[ab]	3.50[a]	3.35[b]	0.086
	0.050	0.050	0.050	0.050	
G:F	0.312[a]	0.290[b]	0.314[a]	0.329[a]	0.003
	0.0071	0.0071	0.0071	0.0071	

[ab]Means within a row with different superscripts differ, $P < 0.05$.

[1]A total of 1,158 finishing pigs (initially 105 ± 2.0 kg BW) were used in a 35-d experiment to evaluate the effects of DDGS withdrawal periods.

[2]Pigs were fed diets containing 30% DDGS until the start of the trial. Diets with DDGS during the trial also contained 30%.

[3]Pens of pigs were topped according to a typical winter marketing strategy with two tops prior to final barn marketing. All pens were topped by removing the 15% heaviest pigs 28 days before final marketing and the 28% heaviest pigs removed 14 days before final marketing. This resulted in a final barn marketing of approximately 57% of starting barn inventory.

[4] Standard error of the means are reported below the treatment means.

[5] Linear, P =0.481; quadratic, P = 0.829.

had increased ($P < 0.05$) ADG compared with pens remaining on the DDGS diet. Feed intake during day 21 to 14 before marketing increased ($P < 0.05$) for pens of pigs switched from DDGS on day 28 before market compared with those still consuming DDGS diets. Pigs with a 35-d withdrawal period had intermediate ADFI ($P > 0.05$). All four treatments were evaluated during day 14 to 7 before market. There was no evidence ($P > 0.05$) for treatment differences in ADG or G:F. ADFI was decreased ($P < 0.05$) for the treatment remaining on DDGS diets compared with all other treatments, which were not different ($P > 0.05$) from each other. During day 7 to 0 before market, ADG and ADFI had marginally significant differences across treatments ($P < 0.086$). Pigs switched from DDGS to CSBM on day 35, 14, or not at all had increased ($P < 0.05$) ADG compared with those with a 28-d withdrawal period before market. Feed intake was increased for pigs switched to CSBM on day 35 or 14 before market compared with those not yet switched ($P < 0.05$). Feed efficiency was poorer ($P < 0.05$) for pigs on the 28-d withdrawal period before market compared with all other treatments, which were similar ($P > 0.05$) to each other.

Both marketing events before the final barn marketing resulted in no evidence for treatment differences in any carcass response criteria ($P >$ 0.132, Table 7), with the exception of HCW at the second marketing (14 d before market), which tended ($P = 0.067$) to be greater for pigs with a 35 d withdrawal period prior or to market compared with those not yet switched. For the final marketing event at the end of the study (day 0), no evidence ($P > 0.224$) for treatment differences were observed for HCW, backfat, loin depth, or percentage lean. Carcass yield increased and belly fat IV decreased (linear, $P < 0.022$) as withdrawal period before marketing increased.

There was no evidence that final BW, overall ADG, or overall G:F differed across treatments (P > 0.116; Table 8); however, ADFI increased (linear, $P = 0.015$) as withdrawal period increased. For the overall carcass data, HCW, backfat, loin depth, and percentage lean were not different based on treatment ($P > 0.05$). Carcass yield increased (linear; $P = 0.034$) with increasing withdrawal period.

DISCUSSION

Literature has demonstrated that DDGS and other high NDF ingredients can decrease carcass yield due to increased gut fill and intestinal weights (Turlington, 1984; Linneen et al., 2008; Asmus et al., 2014). Further, pork fat quality may be negatively impacted as a result of the increased unsaturated fatty acid content of DDGS, which can lead to increased IV (Benz et al., 2008; Graham et al., 2014; Nemechek et al., 2015). To avoid the economic ramifications that result from decreased carcass yield and fat quality, pigs can be switched from diets containing DDGS to CSBM diets before harvest. However, the suggested time of this dietary switch varies within the literature. Some studies suggest 5–10 d (Asmus et al., 2014; Coble et al., 2018), whereas Gaines et al. (2007b) found that 6 wk was necessary to completely recover carcass yield losses. However, it is generally understood that fat quality takes longer to recover than carcass yield following dietary switch from DDGS to CSBM (Asmus et al., 2014).

In our experiments, switching from DDGS to CSBM resulted in a relatively small response, increasing ADG by approximately 0.05 kg (Exp. 1) and ADFI by 0.1 kg (Exp. 2) with neither of these resulting in increased final BW or HCW. We hypothesize that the smaller response in these experiments compared with others is because diets were balanced for NE content. When pigs are switched from a low energy, higher fiber diet to a higher energy, lower fiber diet, they tend to eat similar volumes resulting in greater feed intake on a weight basis. Therefore, when pigs were switched from DDGS to corn-SBM-based diets that contained similar NE levels, there were negligible responses in rate of gain or feed efficiency. Because diets did not differ in energy, pigs did not adjust feed intake as would be expected when dietary energy is manipulated. To the best of our knowledge, these are the first trials conducted with DDGS removal prior to marketing that balanced both the DDGS and CSBM diets for NE.

A more commonly used approach to feeding DDGS involves allowing NE content to change between the DDGS and CSBM diets. In these studies, where diets are not balanced for NE, finishing performance may improve after DDGS are removed from diets due to the increased NE available in the CSBM diets. Asmus et al. (2014) did not balance for NE and observed that removing DDGS and wheat middlings from finishing pig diets improved G:F. Lerner et al. (2019) switched from DDGS to CSBM diets 76 d prior to market and reported linear increases in ADG and G:F with increasing time following dietary switch when diets were not balanced. In an experiment by Graham et al. (2014), pigs were switched from diets containing 30% DDGS and 19% wheat

Table 7. Effects of DDGS withdrawal periods on individual marketing event carcass characteristics, Exp. 2[1,2,3]

	DDGS withdrawal period, d before marketing				Probability, *P*		
Item[4]	35	28	14	0	Trt	Linear	Quadratic
First marketing (day 28 prior to market)							
HCW, kg	93.7	—	—	92.1	0.132	—	—
	0.86	—	—	0.54			
Carcass yield, %	73.7	—	—	73.4	0.484	—	—
	0.33	—	—	0.20			
Backfat, mm[5]	15.7	—	—	14.4	0.605	—	—
	0.40	—	—	0.25			
Loin depth, mm[5]	61.6	—	—	61.2	0.662	—	—
	0.61	—	—	0.40			
Lean, %[5]	54.4	—	—	54.4	0.980	—	—
	0.23	—	—	0.15			
Second marketing (day 14 prior to market)						—	—
HCW, kg	102.5[a]	101.8[ab]	---	100.6[b]	0.067	—	—
	0.66	0.66	---	0.49			
Carcass yield, %	74.9	74.8	---	74.4	0.302	---	---
	0.30	0.30	---	0.22			
Backfat, mm[5]	16.0	15.5	---	15.4	0.329	---	---
	0.32	0.32	---	0.24			
Loin depth, mm[5]	64.4	64.8	---	64.6	0.895	---	---
	0.60	0.59	---	0.44			
Lean, %[5]	54.2	54.3	---	54.4	0.653	---	---
	0.19	0.19	---	0.14			
Final marketing							
HCW, kg	102.1	101.9	102.6	102.0	---	0.935	0.574
	0.60	0.61	0.60	0.60			
Carcass yield, %	75.3	75.3	75.0	74.8	---	0.022	0.854
	0.19	0.19	0.19	0.19			
Backfat, mm[5]	15.6	16.0	15.5	15.4	---	0.224	0.608
	0.24	0.24	0.24	0.24			
Loin depth, mm[5]	65.5	64.9	65.1	65.0	---	0.629	0.603
	0.38	0.38	0.38	0.38			
Lean, %[5]	54.4	54.2	54.4	54.4	---	0.703	0.577
	0.12	0.12	0.12	0.12			
Iodine value[6]	68.1	69.3	70.1	71.7	---	<.0001	0.971
	0.38	0.38	0.37	0.37			

[1]A total of 1,158 finishing pigs (initially 105 ± 2.0 kg BW) were used in a 35-d experiment to evaluate the effects of DDGS withdrawal periods.

[2]Pigs were fed diets containing 30% DDGS until the start of the trial. Diets with DDGS during the trial also contained 30%.

[3]Pens of pigs were topped according to a typical winter marketing strategy with two tops prior to final barn marketing. All pens were topped by removing the 15% heaviest pigs 28 days before final marketing and the 28% heaviest pigs removed 14 days before final marketing. This resulted in a final barn marketing of approximately 57% of starting barn inventory.

[4] Standard error of the means are reported below the treatment means.

[5]Hot carcass weight was used as a covariate.

[6]Belly fat.

middlings to CSBM 24 d prior to market. During the last 24 d, pigs who were switched to the lower NDF/high NE diet had increased ADG and G:F compared with those who continued to consume the high NDF/low NE diet (Graham et al., 2014). Nemechek et al. (2015) also allowed NE level to change in low and high NDF diets and observed increased G:F with the fiber withdrawal. These experiments demonstrate how a dietary switch from lower to higher energy diets may increase the growth rate and feed efficiency of finishing pigs. Thus, it is important to utilize the NE system in diet formulation when using high fiber ingredients to account for the impact of fiber on nutrient digestibility and potential ramifications on growth performance.

Table 8. Effects of DDGS withdrawal periods on overall growth performance and carcass characteristics, Exp. 2[1,2,3]

	DDGS withdrawal period, d before marketing				Probability, *P*	
Item[4]	35	28	14	0	Linear	Quadratic
Growth performance (day -35 to 0)						
ADG, kg	1.05	1.04	1.05	1.02	0.116	0.480
	0.012	0.012	0.012	0.012		
ADFI, kg	3.22	3.18	3.15	3.10	0.015	0.854
	0.035	0.035	0.035	0.036		
G:F	0.327	0.329	0.334	0.331	0.216	0.223
	0.0026	0.0026	0.0026	0.0027		
Final BW, kg	135.8	134.9	136.6	136.0	0.481	0.829
	0.81	0.81	0.81	0.81		
Carcass characteristics						
HCW, kg	101.0	100.6	100.8	100.6	0.610	0.913
	0.46	0.47	0.48	0.48		
Carcass yield, %	75.0	74.9	74.7	74.5	0.034	0.898
	0.17	0.17	0.18	0.18		
Backfat, mm[5]	15.7	15.8	15.3	15.5	0.128	0.423
	0.18	0.18	0.19	0.19		
Loin depth, mm[5]	64.7	64.5	64.7	64.2	0.370	0.587
	0.28	0.28	0.29	0.29		
Lean, %[5]	54.3	54.3	54.5	54.3	0.759	0.388
	0.09	0.09	0.10	0.10		

[1]A total of 1,158 finishing pigs (initially 105 ± 2.0 kg BW) were used in a 35-d experiment to evaluate the effects of DDGS withdrawal periods

[2]Pigs were fed diets containing 30% DDGS until the start of the trial. Diets with DDGS during the trial also contained 30%.

[3]Pens of pigs were topped according to a typical winter marketing strategy with two tops prior to final barn marketing. All pens were topped by removing the 15% heaviest pigs 28 days before final marketing and the 28% heaviest pigs removed 14 days before final marketing. This resulted in a final barn marketing of approximately 57% of starting barn inventory.

[4] Standard error of the means are reported below the treatment means.

[5] HCW was used as a covariate.

Carcass yield can be impacted by DDGS due to the ability of fiber to increase the weight and contents of the intestinal tract (Turlington, 1984; Asmus et al., 2014). The observed carcass yield response in the present experiment is largely consistent with other experiments that fed DDGS prior to market. Coble et al. (2017) fed 0% or 30% DDGS for 20 d prior to market and observed no final BW effects, but feeding DDGS decreased HCW and yield. This response is consistent with much of the literature evaluating removing DDGS from the diet before harvest (Gaines et al., 2007a; Nemechek et al., 2015). Though the impact of feeding DDGS on carcass yield is well understood, the suggested time to remove DDGS from diets to restore yield varies. Nemechek et al. (2015) reported that switching from high NDF to low NDF diets for 17-d improved carcass yield compared with no dietary withdrawal period but was still decreased compared with a lower NDF control regimen fed for longer than 17 d. Coble et al. (2018) and Asmus et al. (2014) estimated that 5–10 d withdrawal periods could recover yield, but Gaines et al. (2007b) reported that 42 d was necessary to fully recover yield. Our current study suggests that the complete recovery period for yield is at least 35 d, but due to the linear nature of the response, the appropriate withdrawal time for full recovery may be longer. However, partial recovery can be observed in as little as 14 d.

Soto et al. (2019) developed a regression model to predict carcass yield based on NDF level in the diets immediately before harvest. This equation predicted a 1.0%, 1.0%, and 0.9% increase in carcass yield for Exp. 1 for durations of CSBM feeding of 28, 21, and 14 d, respectively. The actual carcass yield increased by 1.1, 0.8, and 0.9%. Experiment 2 had predicted increases in carcass yield of 1.2, 1.1, and 1.0 with a 35, 28, and 14 d withdrawal periods, respectively. The actual increases were more variable at 0.5%, 0.4%, and 0.2%. The equation of Soto et al. (2019) appears to be a useful tool to determine expected carcass yield with varying dietary NDF levels and dietary changes; however, the reason that yield was not as greatly affected in the second experiment as in the first experiment remains unknown.

Regardless of dietary energy content, feeding DDGS consistently results in poorer fat quality, which can be measured by carcass fat IV. Increased IV indicates increased levels of unsaturated fatty acids. In both Exps. 1 and 2, IV increased by approximately 2–3 units, which could become meaningful if pigs are marketed to processing facilities that have quality control standards for carcass fat IV. Nevertheless, this response in belly fat IV is consistent with other literature where increased DDGS withdrawal period prior to harvest decreased IV (Benz et al., 2008; Asmus et al., 2014; Nemechek et al., 2015).

The outcomes of both experiments were largely similar, regardless of marketing strategy. Carcass yield and belly fatty acid composition were negatively impacted, but this was driven by the pigs in the last market load that had been consuming their respective diets for the longest duration. Thus, in these experiments, the impact of withdrawing DDGS from the diet was similar across two different seasonal marketing strategies. Nevertheless, further information regarding ingredient and carcass prices could influence the optimal timing of dietary fiber withdrawal period and marketing strategy for maximizing profitability.

In summary, switching from DDGS diets to CSBM diets that were balanced for net energy had negligible effects on growth performance, regardless of whether one or two marketing events were implemented during the marketing period. However, in both studies, yield was increased and IV was decreased up to the 35 or 28 d withdrawal periods. Therefore, these data show that longer withdrawal periods from high to low NDF diets may be useful to increase yield and improve carcass fatty acid saturation.

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