

Effects of switching from corn distillers dried grains with solubles- to corn- and soybean meal-based diets on finishing pig performance, carcass characteristics, and carcass fatty acid composition

Annie B. Lerner,[†] Mike D. Tokach,[†] Joel M. DeRouche,[†] Steve S. Dritz,^{‡,◊} Robert D. Goodband,^{†,1} Jason C. Woodworth,[†] and Matt Allerson^{||}

[†]Department of Animal Sciences and Industry, College of Agriculture, Kansas State University, Manhattan 66506-0201; [‡]Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University, Manhattan 66506-0201; and ^{||}Holden Farms, Inc., Northfield, MN, 55057

ABSTRACT: Corn distillers dried grains with solubles (DDGS) are known to negatively impact carcass yield and fat quality, thus finishing pigs may need to be switched from diets containing DDGS to corn-soybean meal (CSBM) diets before marketing (DDGS withdrawal). A total of 860 finishing pigs (PIC C48 or L42 × 327; initially 66.2 kg body weight, BW) were used in a 76-day experiment to evaluate the effects of DDGS withdrawal periods at increasing intervals before harvest. Pen served as the experimental unit, and there were seven replicate pens per treatment with 23 to 25 pigs per pen. Pens were blocked by BW and allotted to one of five dietary treatments differentiated by the DDGS withdrawal period: 76, 42, 27, 15, or 0 day before harvest. Diets contained 40% DDGS from 22 to 66 kg prior to the experiment, 0% or 35% DDGS during the experiment from ~66 to 82 kg, and 0% or 30% DDGS until the completion of the trial. Diets were not balanced for net energy. Linear and quadratic response to time following dietary switch was evaluated using PROC GLIMMIX. For the overall period (day 76 prior to market to day 0), as withdrawal period increased, average daily gain (ADG) and final BW

increased (linear, $P < 0.002$) and feed efficiency (G:F) improved (quadratic, $P = 0.019$). Average daily feed intake increased (quadratic, $P = 0.030$) as withdrawal period increased. There was an increase (linear $P = 0.010$) in hot carcass weight (HCW), with a marginally significant increase in carcass yield (linear, $P = 0.094$) with increasing withdrawal period. Loin depth and lean percentage did not demonstrate any evidence for treatment differences ($P > 0.132$). Backfat increased (linear, $P = 0.030$) with increasing withdrawal period. Finally, iodine value (IV) of belly fat was decreased (linear, $P = 0.001$) with increased withdrawal period. In conclusion, switching from a DDGS-based diet to a CSBM-based diet for longer periods before slaughter increased ADG and improved G:F, resulting in increased HCW. After diets were switched from DDGS to CSBM, pigs demonstrated an increase in intake, likely due to the ability to consume high volumes of feed after consuming high fiber (DDGS) diets. Belly fat IV was decreased as the length of time after dietary change was increased, with the lowest IV resulting from pigs that consumed CSBM for the entire experimental period.

Key words: carcass fatty acid, DDGS, fiber reduction, finishing pigs, growth

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¹Corresponding author: goodband@ksu.edu

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INTRODUCTION

Corn distillers dried grains with solubles (DDGS) are commonly included in swine diets to partially replace corn and soybean meal (CSBM). Several studies have demonstrated that the addition of up to 30% DDGS does not negatively impact growth rate (DeDecker et al., 2005; Stein and Shurson, 2009). However, increased neutral detergent fiber (NDF) in the digestive tract increases gut fill and intestinal weight and therefore can result in reduced carcass yield for pigs consuming high NDF diets compared with their counterparts consuming a diet with lower NDF (Gaines et al., 2007; Soto et al., 2019). In addition to a high NDF content, DDGS also contain increased concentrations of unsaturated fatty acids, which may result in reduced fat quality (Stein and Shurson, 2009; Graham et al., 2014b).

Many authors have evaluated the effects of switching from diets containing high NDF to those which contain only CSBM as the primary protein and energy sources (Asmus et al., 2014; Graham et al., 2014a; Coble et al., 2018). Their findings largely conclude that switching from high NDF to low NDF (CSBM-based diets) ~24 d before market can mitigate negative impacts on yield, while pork fat firmness as indicated by iodine value (IV) may take longer to restore; however, these studies employed both DDGS and wheat middlings to increase NDF. Jacela et al. (2009) determined that a 3- or 6-week withdrawal period did not impact growth performance but significantly improved fatty acid (FA) saturation for pigs switched from DDGS as measured by IV. In regards to finishing growth performance, some authors have reported improvements following a switch to a lower fiber diet (Asmus et al., 2014; Coble et al., 2018) while some report no change (Hilbrands et al., 2013; Lerner et al., 2020). Therefore, it is important to understand the ideal timing of dietary switch from DDGS-containing to CSBM-based diets (or withdrawal period) and the subsequent impact on finishing pig growth performance, carcass characteristics, and carcass fat IV. The objective of this study was to understand the impacts of switching from DDGS to low NDF diets at increasing intervals starting 76 days before harvest in a commercial facility on growth, carcass characteristics, and carcass FA composition.

MATERIALS AND METHODS

General

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 (Holden Farms, Inc., Northfield, MN). The barn was double-curtain sided with completely slatted concrete flooring and deep pits for manure storage. Each pen (3.05 × 5.48 m) was equipped with adjustable gates and contained a three-hole, dry feeder with each space being 38.1 cm wide (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 pigs (PIC 327 × C48/L42, Hendersonville, TN; initial average body weight [BW] of 66.2 ± 5.03 kg) were used in the 76-day growth study. Pen was the experimental unit, and there were seven replicate pens per treatment with 23 to 25 pigs per pen. Pens were blocked by BW and randomly assigned within block to one of five dietary treatments differentiated by the number of days prior to slaughter that diets containing DDGS were replaced with CSBM-based diets. Pigs were switched from a DDGS-based diet to CSBM at 76, 42, 27, 15, or 0 day (no dietary switch) before harvest. All pigs were provided 40% DDGS prior to the test period (22 to 66 kg).

Pens of pigs were weighed and feed disappearance was measured on days 76, 42, 27, 15, and 0 prior to marketing to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (G:F). In the case of a pig removal due to illness or death, pen gates were adjusted to maintain the desired floor space allowance (0.70 m²/pig).

Pigs were given ad libitum access to feed and water throughout the study. Diets were fed in four sequential phases from ~66 to 82, 82 to 104, 104 to 122, and 122 kg until the end of the study (Table 1). Diets with DDGS contained 35% from ~66 to 82 kg and 30% in the remaining dietary phases. Diets were formulated to meet or exceed NRC (2012) recommendations for the nutrient requirements. Diets contained 3.6, 3.2, 3.0, and 3.0 g standardized ileal digestible (SID) Lysine (Lys) per Mcal of net energy (NE) in phases 1 through 4, respectively, and required Lys:NE ratio was derived from the genetic supplier's prediction equation based on commercial experiments (Gonçalves et al., 2017). NE of DDGS was calculated using an assumed oil content (7.5%) based on an equation by Nitikanjana et al. (2013) and NRC (2012) values used for CSBM. Proximate analysis was completed on DDGS samples during the time of the trial and resulted in 90.5% dry matter (DM), 26.7% crude protein (CP), 7.6% crude fiber, and 8.8% ether extract. All diets were fed

Table 1. Diet composition, phases 1 through 4

Ingredient, %	Dietary phase							
	DDGS ¹				Corn soybean meal			
	1 ²	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% CP	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-Lys 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 ³	0.20	0.15	0.10	0.10	0.20	0.15	0.10	0.10
Phytase ⁴	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								
SID amino acids, %								
Lys:net energy, g/Mcal	3.56	3.15	3.04	3.04	3.56	3.15	3.04	3.06
Lys	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 + cysteine: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/kg	2,469	2,487	2,487	2,502	2,500	2,520	2,526	2,533
CP, %	17.8	16.7	16.9	16.4	15.4	14.3	13.9	14.0
Ca, %	0.54	0.53	0.51	0.45	0.54	0.53	0.53	0.45
P, %	0.42	0.40	0.40	0.38	0.49	0.47	0.45	0.42
Available P, %	0.35	0.33	0.32	0.29	0.35	0.34	0.32	0.29
Analyzed composition, % ⁵								
DM	88.7	88.5	88.4	88.9	87.5	88.2	87.4	87.3
CP	16.0	16.1	16.6	16.8	14.8	12.8	12.5	12.6
ADF	6.5	6.7	6.2	5.4	3.0	2.9	3.1	3.5
Neutral detergent fiber	12.9	12.1	12.6	12.0	5.7	6.3	6.5	6.1
Calcium	0.74	0.65	0.69	0.63	0.71	0.93	0.69	0.65
Phosphorus	0.59	0.50	0.54	0.51	0.51	0.45	0.46	0.40
Ether extract	4.80	4.30	4.20	4.40	2.70	2.70	3.00	2.90

¹DDGS = corn distillers dried grains with solubles.

²Diets were fed in four sequential phases from ~66 to 82, 82 to 104, 104 to 122, and 122 until 131 kg.

³Provided 1,543,220 IU vitamin A from vitamin A acetate; 440,920 IU vitamin D from vitamin D₃; 8,047 IU vitamin E from DL- α -tocopherol acetate; 882 mg menadione from menadione nicotinamide bisulfite; 8 mg B₁₂ from cyanocobalamin; 14,991 mg niacin from niacinamide; 6,614 pantothenic acid from d-calcium pantothenate; 1,984 mg riboflavin from crystalline riboflavin; 3 g Cu from copper sulfate; 160 mg Ca from calcium iodate; 31 mg Fe from ferrous sulfate; 3 g Mn from manganese sulfate; 120 mg Se from sodium selenite; and 31 g Zn from zinc sulfate per kilogram of premix.

⁴Ronozyme HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided 1,102,300 phytase units/kg of product with an assumed release of 0.14% and 0.12% available P for 0.1% and 0.8% inclusion levels, respectively.

⁵Samples were analyzed at Ward Laboratories (Kearney, NE).

in meal form and manufactured at a commercial feed mill (Blooming Prairie, MN). 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), acid detergent fiber (ADF) and NDF (Van Soest et al., 1991), and ether extract (method 920.39; AOAC International, 1990).

According to typical farm procedures, the four heaviest pigs were removed from each pen 15 days prior to the final barn marketing event, weighed, tattooed, and transported to a USDA-inspected packing plant (Tyson Fresh Meats, Waterloo, IA) for carcass data collection. Similarly, for the final barn marketing, all pigs were weighed and tattooed with pen identification number and pigs were then processed for data collection. Carcass measurements collected included hot carcass weight (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, belly fat samples (anterior to the manubrium) were collected from two pigs per pen during processing prior to carcass chilling. These samples were analyzed via gas chromatography according to procedures by Cromwell et al. (2011) for FA analysis to calculate an IV according to the NRC (2012) standard equation as a percent of ether extract and FA.

Statistical Analysis

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, BW as blocking factor, and treatment as fixed effect. For intermediate periods, one-way ANOVA was utilized to evaluate the response between pens that had been switched from DDGS- to CSBM-based diets vs. those pens that remained on DDGS diets at that point in time. 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 withdrawal period duration. These coefficients were generated using PROC IML to account for unevenly spaced d of withdrawal. Block was removed for FA and IV analysis as its variance component estimate converged to 0. 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 when the overall F -test resulted in $P < 0.05$.

RESULTS

Analyzed values for DM, CP, ADF, NDF, Ca, and P content of experimental diets (Table 1) were consistent with formulated estimates. In diets containing DDGS, ADF and NDF content was approximately two times the level analyzed in CSBM diets. These NDF levels are similar to other published values for diets containing 30% DDGS (Lerner et al., 2020). A mycotoxin analysis of the DDGS was not conducted.

BWs on days 76, 42, 27, and 15 prior to market showed no evidence for treatment differences (Table 2). During the period following dietary switch from days 76 to 42 prior to market, two treatments were evaluated: either switched from DDGS at day 76 before market or not yet switched. ADG and G:F improved ($P < 0.001$) for pigs switched from DDGS (40% during the pretest period) to CSBM diets on day 76 prior to market, but there was no evidence that feed intake was different between treatments. The following period (days 42 to 27 before market) evaluated a dietary switch from DDGS to CSBM at 76 or 42 days before market vs. no dietary switch and resulted in no evidence for differences in ADG, ADFI, or G:F. From 27 to 15 days before market, ADG tended to be greater ($P = 0.053$) for pigs switched for CSBM on day 42 compared with no withdrawal with those switched on days 76 and 27 intermediate. Pigs still fed DDGS-based diets had decreased ($P < 0.05$) ADFI compared with those pigs switched from DDGS on either day 42 or 27 before market, which were not different from each other. Pigs with a DDGS withdrawal period of 76 days prior to market had intermediate feed intake to all treatments. There was no evidence for a treatment difference in G:F.

Finally, from 15 days before market to marketing (day 0) pigs switched to CSBM on day 15 before market had increased ($P < 0.05$) ADG compared with pigs switched on day 76 before market or those not switched. Furthermore, pigs switched to CSBM on day 27 before market had increased ($P < 0.05$) ADG compared with those pigs not switched from DDGS diets. ADFI was decreased ($P < 0.05$) in pigs with no dietary switch compared with those switched on day 42, 27, or 15 before market, but not different from with a 76-day withdrawal period before market. Additionally, ADFI was decreased ($P < 0.05$) for pigs on the 76-day withdrawal period before market compared with those switched to CSBM on day 27 before market. There was no evidence for a treatment difference in G:F.

Table 2. Effects of switching from diets containing DDGS to CSBM-based diets prior to market on growth performance^{1,2}

Item ³	DDGS withdrawal period before market, day					<i>P</i>
	76	42	27	15	0	
BW, kg						
Days 76	66.1	—	—	—	66.2	0.906
	2.00	—	—	—	1.77	
Days 42	102.1	100.0	—	—	99.9	0.278
	2.26	2.26	—	—	2.04	
Days 27	113.5	110.6	111.0	—	110.7	0.192
	2.29	2.29	2.29	—	1.16	
Days 15	121.4	119.9	119.9	118.3	118.5	0.451
	2.30	2.30	2.30	2.30	2.30	
Days 76 to 42						
<i>n</i> (pens):	7	—	—	—	28	
ADG, kg	1.06 ^a	—	—	—	0.98 ^b	0.001
	0.023	—	—	—	0.020	
ADFI, kg	2.71	—	—	—	2.67	0.265
	0.092	—	—	—	0.087	
G:F	0.392 ^b	—	—	—	0.370 ^a	0.001
	0.0066	—	—	—	0.0058	
Days 42 to 27						
<i>n</i> (pens):	7	7	—	—	21	
ADG, kg	0.75	0.71	—	—	0.72	0.565
	0.033	0.033	—	—	0.020	
ADFI, kg	2.60	2.59	—	—	2.67	0.374
	0.12	0.12	—	—	0.109	
G:F	0.293	0.277	—	—	0.271	0.379
	0.0148	0.0148	—	—	0.0096	
Days 27 to 15						
<i>n</i> (pens):	7	7	7	—	14	
ADG, kg	0.70 ^x	0.76 ^y	0.71 ^x	—	0.63 ^z	0.053
	0.042	0.042	0.042	—	0.033	
ADFI, kg	2.63 ^{a,b}	2.78 ^a	2.74 ^a	—	2.43 ^b	0.004
	0.084	0.084	0.084	—	0.063	
G:F	0.265	0.276	0.261	—	0.259	0.773
	0.0149	0.0149	0.0149	—	0.0115	
Days 15 to 0						
<i>n</i> (pens):	7	7	7	7	7	
ADG, kg	0.94 ^{b,c}	0.97 ^{a,b,c}	1.00 ^{a,b}	1.03 ^a	0.89 ^c	0.018
	0.028	0.028	0.028	0.028	0.028	
ADFI, kg	3.24 ^{b,c}	3.33 ^{a,b}	3.44 ^a	3.37 ^{a,b}	3.11 ^c	0.002
	0.067	0.067	0.067	0.067	0.067	
G:F	0.291	0.291	0.290	0.306	0.287	0.291
	0.0089	0.0089	0.0089	0.0089	0.0089	

^{abc}Means lacking common superscripts differ ($P < 0.05$).

^{xyz}Means lacking common superscripts differ ($P < 0.10$).

¹A total of 860 finishing pigs (initially 66.1 ± 5.03 kg) were used in a 76-day experiment to evaluate the effects of increasing corn dried distillers grains with solubles (DDGS) withdrawal period prior to harvest.

²All pigs were fed diets containing 40% DDGS until the start of the trial (22 to 66 kg). Diets with DDGS during the trial contained 35% from ~66 to 82 kg and 30% until the completion of the trial.

³Standard error of the means are reported below the treatment means.

Overall growth performance was evaluated using linear and quadratic contrasts to determine the effect of time of dietary switch from DDGS to CSBM (Table 3). For the overall period (day 76

before market to 0), withdrawal period increased, ADG and final BW increased (linear, $P < 0.018$) and G:F improved (quadratic, $P = 0.022$) for pigs switched from diets containing DDGS to diets

Table 3. Effects of switching from diets containing DDGS with solubles to CSBM-based diets prior to market overall growth performance and carcass characteristics finishing pigs ^{1,2,3}

Item	DDGS withdrawal period before market, day					SEM	P	
	76	42	27	15	0		Linear	Quadratic
Growth performance								
<i>Days 76 to 0</i>								
ADG, kg	0.92	0.88	0.89	0.88	0.86	0.012	0.002	0.973
ADFI, kg	2.78	2.80	2.85	2.77	2.73	0.071	0.251	0.030
G:F	0.330	0.315	0.315	0.320	0.316	0.0063	0.003	0.019
Final BW, kg	133.8	131.7	132.0	130.6	128.6	2.22	0.018	0.573
Carcass characteristics								
HCW, kg	99.1	97.7	97.2	96.1	94.8	1.82	0.010	0.554
Carcass yield, %	73.6	73.6	73.3	73.0	73.0	4.13	0.094	0.615
Loin depth, mm ³	71.8	72.0	71.8	72.4	72.7	0.71	0.335	0.532
Backfat, mm ³	13.1	12.7	13.2	12.7	12.1	0.68	0.030	0.084
Lean, % ³	57.1	57.2	57.1	57.3	57.4	0.20	0.132	0.232

¹A total of 860 finishing pigs (initially 66.1 ± 5.03 kg) were used in a 76-day experiment to evaluate the effects of increasing corn DDGS withdrawal period at varying time intervals prior to harvest.

²Pigs were fed diets containing 40% DDGS until the start of the trial (22 to 66 kg). Diets with DDGS during the trial contained 35% from ~66 to 82 kg and 30% until the completion of the trial.

³HCW was used as a covariate for loin depth, backfat, and percent lean.

without DDGS. ADFI increased (quadratic, $P = 0.030$) with increasing withdrawal period with the greatest ADFI observed in those pigs switched from DDGS 27 days before marketing. The response detected in final BW resulted in an increase (linear, $P = 0.009$) in HCW, with a marginally significant response for improved carcass yield (linear, $P = 0.094$) with increasing withdrawal period. Loin depth and lean percentage did not demonstrate any evidence for treatment differences. Backfat was increased (linear, $P = 0.030$) with increasing withdrawal period.

There was no statistical evidence that withdrawal period impacted individual FA concentrations (Table 4), with the exception of palmitoleic acid, which displayed a marginally significant reduction (linear, $P = 0.071$) with decreasing withdrawal period. IV of belly fat was decreased (linear, $P < 0.034$) with increased withdrawal period when calculated both as a percent of FA and a percent of ether extract.

DISCUSSION

Corn DDGS are a good source of amino acids, energy, and P in swine diets. It has been demonstrated that DDGS can be fed to growing and finishing pigs at 15% of the diet without impacting growth performance (Linneen et al., 2008) while others suggest that up to 30% may have no detrimental effects (DeDecker et al., 2005; Stein and Shurson, 2009). Further, Hilbrands et al. (2013) report that DDGS can be abruptly added or

removed from the diets with no negative impacts on finishing pig growth performance. Though DDGS can be an economically attractive ingredient to include in swine diets, they contain high NDF content, which can negatively impact nutrient digestibility and carcass yield (Stein et al., 2016; Soto et al., 2019). Additionally, the oil content in DDGS contains increased concentration of unsaturated FAs, making feeding DDGS to finishing pigs a fat quality concern (Whitney et al., 2006). Given the negative effects of feeding DDGS on carcass yield and carcass fat IV, switching to a CSBM diet before slaughter (or a withdrawal period) might mitigate these undesirable responses.

The impact of removing DDGS from finishing diets on growth performance is variable within the literature. In Graham et al. (2014a), switching from a diet containing 30% DDGS- and 17% wheat middlings to CSBM for 24 days before marketing increased ADG compared with no dietary switch, but feeding CSBM for the entire 73-day experiment further increased ADG and G:F compared with the DDGS and wheat middlings removal strategy. Gaines et al. (2007) did not observe differences in ADG or ADFI within 3- or 6-week DDGS withdrawal period compared with 70 days of continuous CSBM or 30% DDGS diets, yet feeding DDGS for 70 days reduced G:F compared with CSBM. On the other hand, Coble et al. (2018) reported minimal differences in performance when switching pigs from high to low NDF diets for 0 to 24 days before marketing, although continuous feeding of CSBM for 96 days compared with all DDGS withdrawal

Table 4. Effects of switching from diets containing DDGS to CSBM-based diets prior to market on FA analysis of belly fat samples^{1,2}

Item ³	DDGS withdrawal period before market, day					SEM	P	
	76	42	27	15	0		Linear	Quadratic
Myristic acid (C14:0), %	1.93	2.06	1.70	1.87	1.74	0.142	0.261	0.586
Palmitic acid (C16:0), %	29.13	29.81	27.56	29.72	25.77	1.945	0.329	0.385
Palmitoleic acid (C16:1), %	3.87	4.12	3.17	3.76	3.13	0.291	0.071	0.382
Stearic acid (C18:0), %	7.86	7.03	9.28	7.85	9.25	1.237	0.411	0.605
Oleic acid (C18:1 <i>cis</i> -9), %	37.25	35.70	37.44	34.85	38.27	2.736	0.959	0.571
Linoleic acid (C18:2n-6), %	15.07	16.33	16.63	16.71	17.61	1.508	0.243	0.995
Arachidic acid+ γ -linolenic acid (C20:0+C18:3n-6), %	0.33	0.37	0.29	0.33	0.28	0.033	0.243	0.349
α -Linolenic acid (C18:3n-3), %	0.72	0.73	0.63	0.69	0.60	0.070	0.209	0.640
Gadoleic acid (C20:1), %	0.65	0.78	0.67	0.70	0.80	0.075	0.292	0.982
Dihomo- γ -linolenic (C20:3n-6), %	0.09	0.12	0.07	0.09	0.15	0.028	0.387	0.429
Arachidonic acid (C20:4n-6), %	0.36	0.37	0.37	0.39	0.35	0.036	0.918	0.680
Other FA, %	2.70	2.58	2.12	2.68	2.03	0.362	0.275	0.827
IV, % of EE ⁴	68.1	69.5	70.0	68.7	72.6	1.13	0.031	0.365
IV, % of FA ³	65.2	66.5	67.0	65.8	69.4	1.08	0.030	0.364

¹A total of 860 finishing pigs (initially 66.1 ± 5.03 kg) were used in a 76-day experiment to evaluate the effects of increasing corn DDGS withdrawal period at varying intervals prior to harvest. Belly fat samples were collected from 2 pigs/pen to perform FA analysis via gas chromatography.

²Pigs were fed diets containing 40% DDGS until the start of the trial (22 to 66 kg). Diets with DDGS during the trial contained 35% from ~66 to 82 kg and 30% until the completion of the trial.

³FA values obtained via gas chromatography (GC). IV was calculated according to the [NRC \(2012\)](#) equation and consider FA as a percent of total FA: Iodine value = [% C16:1] \times 0.9502 + [% C18:1] \times 0.8598 + [% C18:2] \times 1.7315 + [% C18:3] \times 2.6152 + [% C20:1] \times 0.7852 + [% C22:1] \times 0.7225 + [% C22:5] \times 3.6974 + [% C22:6] \times 4.4632.

⁴FA concentrations were obtained via gas chromatography. IV was calculated according to the [NRC \(2012\)](#) equation and consider FA as a percent of ether extract (EE): IV = [% C16:1] \times 0.9976 + [% C18:1] \times 0.8985 + [% C18:2] \times 1.8099 + [% C18:3] \times 2.7345 + [% C20:1] \times 0.8173 + [% C22:1] \times 0.7496 + [% C22:5] \times 3.8395 + [% C22:6] \times 4.6358.

period treatments improved ADG, G:F, and final BW. [Asmus et al. \(2014\)](#) observed improved G:F with increasing DDGS and wheat middlings withdrawal period. The observed improvements in growth rate and G:F are possibly a function of increased NE content of CSBM diets compared with DDGS-based diets. Pigs in the current experiment which were switched from DDGS at 76 days prior to market to a CSBM-based diet had increased ADG and G:F. Given that feed intake of this potentially higher energy diet increased, growth rate was further improved following the dietary switch.

A value of 7.5% oil was assumed in order to determine an energy value for the DDGS used in this study ([Graham et al., 2014b](#)); however, the actual oil content was 8.8%. If this was indeed the case, the estimated energy values of the diets containing DDGS would have been ~30 kcal/kg of NE greater, or very similar to the CSBM diets. In a previous study, [Lerner et al. \(2020\)](#) observed few differences in growth performance during various withdrawal periods of DDGS when NE was balanced between DDGS- and CSBM-based diets. In a previous study by [Lerner et al. \(2020\)](#), they switched from DDGS- to CSBM-based diets balanced for NE and found no evidence for differences

in growth performance. Because there were indeed differences in growth performance after switching from DDGS- to CSBM-based diets, this might imply that differences in bulk density among diets might be a contributing factor in the responses observed herein.

Increases in feed intake following dietary switch were observed for overall ADFI, as well as some intermediate periods in the current experiment. This is notable because pigs actually increased consumption of a potentially more energy-dense diet, or one with greater bulk density. [Asmus et al. \(2014\)](#) and [Coble et al. \(2018\)](#) observed a similar effect following a switch from DDGS and wheat middlings to CSBM and proposed that this response is related to gut fill capacity. When pigs are switched from high- to low-fiber diets, they may naturally continue to consume the same volume of feed, which is actually increased feed on a weight basis due to the greater bulk density of the CSBM diet. It appears that this phenomenon can be regulated over time, which describes the quadratic response in the overall ADFI.

Fiber has been demonstrated to decrease carcass yield due to its ability to increase intestinal fill and intestinal weight ([Turlington, 1984](#);

Asmus et al., 2014). The efficacy of switching pigs from high NDF to lower NDF, CSBM diets prior to harvest to recover carcass yield is well documented, and many researchers utilized diets that contained both 30% DDGS and 19% wheat middlings to increase dietary NDF level (Asmus et al., 2014; Graham et al., 2014a; Nemechek et al., 2015; Coble et al., 2018). Using this combination of DDGS and wheat middlings, Asmus et al. (2014) reported that carcass yield losses were recovered within a 23-day withdrawal period, while Coble et al. (2018) noted that carcass yield and HCW could be recovered in as little as 9 days. Conversely, others have reported that 17- to 24-day withdrawal periods only provided partial carcass yield recovery (Graham et al., 2014a; Nemechek et al., 2015), but carcass yield was still less than that of pigs consuming CSBM throughout the entire experiment (Nemechek et al., 2015). When feeding 30% DDGS alone (without wheat middlings), Gaines et al. (2007) observed that a 42-day withdrawal period was enough time to recover carcass yield. In the current experiment, HCW and carcass yield were both improved with increased withdrawal period. Though the duration of withdrawal period in the present experiment is longer than many of the aforementioned studies, the data agree with most of the previous studies in that carcass yield may begin to numerically recover in a 27-day withdrawal period. However, due to the linear nature of the response in HCW and carcass yield observed in this experiment, pigs needed at least a 76-day withdrawal period, which agrees with Nemechek et al. (2015). The need for a longer withdrawal period than reported in Asmus et al. (2014) and Coble et al. (2018) may be dependent on other unknown factors such as pretrial feeding regimens, specifically the NDF content of diets prior to the beginning of the experiments. Pigs in the current experiment consumed 40% DDGS starting at 20 kg, possibly making a longer fiber reduction period necessary.

Soto et al. (2019) used meta-analysis to model the change in yield with increased withdrawal period and various NDF levels. This model predicted a 1.0%, 0.9%, 0.7%, and 0.6% increase in yield for the 76-, 42-, 27-, or 15-day withdrawal periods, respectively, prior to market. In the present data, yield was increased by 0.6%, 0.6%, 0.3%, or 0% for the four withdrawal periods. This model seems to be a useful tool to understand the impact of NDF on carcass yield, though the current data have a longer withdrawal period than the studies included in the

meta-analysis, which may cause some variation in the estimates.

Another response with economic implications is carcass fat IV, which many pork processors monitor and enforce discounts beyond a given threshold. IV, which is an indication of the level of unsaturated FAs present in carcass fat deposits, is generally increased when DDGS are fed due to the unsaturated FAs found in corn oil (Stein and Shurson, 2009). Softer pork fat resulting from increased levels of unsaturation may cause undesirable pork quality (Widmer et al., 2008; Garnsworthy and Wiseman, 2009). Xu et al. (2010) suggest that a three-week withdrawal period could lower carcass fat IV to levels of pigs not fed DDGS; however, other evidence suggest that this may take longer to recover. Jacela et al. (2009) reported that a six-week withdrawal period did not completely restore carcass fat IV when comparing feeding 30% DDGS to no DDGS. The present study found that carcass fat IV continued to decrease up to the 76 d withdrawal period, yet a numerical reduction was found even when withdrawing DDGS for only 15 days, which is in agreement with other literature (Asmus et al., 2014; Coble et al., 2018).

In conclusion, switching from DDGS to CSBM diets starting at 76 days prior to market increased growth rate and G:F, which resulted in an additional 5 kg of HCW. This response is primarily due to increased NE content and reduced fiber level of diets without DDGS. IV was decreased with increased DDGS withdrawal period, yet improvement was seen with withdrawal periods as short as 15 days. Therefore, strategies that switch from DDGS- to CSBM-based diets may be useful to reduce the negative effects of DDGS on growth performance, reduced carcass weights and yield, and decreased fat saturation. Feeding DDGS for extended periods during the finishing period may result in poorer pig performance compared with CSBM if the difference in NE is not accounted for.

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