The Effects of Sorghum Dried Distillers Grains with Solubles on Finishing Pig Growth Performance, Carcass Characteristics, and Fat Quality[1]

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Summary

A total of 288 finishing pigs (PIC TR4 × 1050, initially 129.6 lb) were used in a 73-d study to determine the effects of increasing sorghum dried distillers grains with solubles (DDGS) in sorghum- or corn-based diets on finishing pig growth performance, carcass characteristics, and fat quality. Pigs were allotted to 1 of 6 dietary treatments in a completely randomized design based on initial pen weight. The dietary treatments included sorghum-based diets with sorghum DDGS included at 0, 15, 30, or 45%; a sorghum-based diet with 30% corn DDGS; and a corn-based diet with 30% corn DDGS. Overall (d 0 to 73), increasing sorghum DDGS from 0 to 45% reduced (linear, $P < 0.04$) ADG and ADFI. Increasing sorghum DDGS increased (linear, $P < 0.01$) backfat iodine value (IV), and fat color became less red (a*; linear, $P < 0.01$) and tended to be less yellow (b*; linear, $P < 0.06$). No differences were observed in growth performance among pigs fed corn- or sorghum-based diets with 30% corn DDGS along with similar carcass characteristics, backfat, loin depth, fat-free lean index (FFLI), HCW, carcass yield, and backfat IV. Pigs fed sorghum-based diets with either 30% sorghum or corn DDGS had similar ADG, ADFI, and F/G, as well as similar carcass characteristics; however, pigs fed 30% sorghum DDGS had decreased ($P < 0.01$) backfat IV and fat color that was more white (L*) and less yellow (b*) in color than pigs fed 30% corn DDGS.

We observed similar ADG, ADFI, and F/G, as well as carcass characteristics, for pigs fed corn- or sorghum-based diets with 30% DDGS. Backfat IV was greater in pigs fed increasing DDGS, with a notable increase in pigs fed corn DDGS compared with those fed sorghum DDGS. Feeding sorghum DDGS produces pork fat that is lighter in color and less yellow than those fed corn DDGS, which may have an important role in pork export markets.

Key words: corn, DDGS, finishing pig, sorghum

Introduction

In the Great Plains region of the United States, sorghum is grown due to its ability to survive in drought conditions. Due to the large production of sorghum in the area and

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its use in ethanol production, sorghum DDGS are more available to swine producers than corn DDGS.

Sorghum has a feeding value of 96 to 100% that of the value of corn, and produces similar pig growth performance when used to completely replace corn when formulated in swine diets; however, although a large database of information is available on the nutritional value of sorghum, little is known about sorghum DDGS. Therefore, more research needs to be conducted to determine the feeding value of sorghum DDGS. The objective of this study was to compare corn- vs. sorghum-based diets and determine the effects of increasing sorghum-DDGS on finishing pig growth performance, carcass characteristics, and fat quality.

Procedures

The protocol for this study was approved by the Kansas State University Institutional Animal Care and Use Committee. The study was conducted at the K-State Swine Teaching and Research Center, Manhattan, KS.

The sorghum, corn, sorghum DDGS, and corn DDGS and were analyzed for their amino acid profile at the University of Missouri-Columbia Agricultural Experiment Station Chemical Laboratories (Columbia, MO). Standardized ileal digestibility values for the sorghum DDGS were derived from Urriola et al. (2009[3]). These values were then used in diet formulation (Table 1). Fatty acid analyses were conducted on the corn, sorghum, corn DDGS, and sorghum DDGS utilized in the study at the Kansas State University Analytical Lab (Manhattan, KS; Table 2). Bulk densities (lb per bushel) were also measured among the treatment diets (Table 3).

A total of 288 finishing pigs (PIC TR4 × 1050, initially 129.6 lb) were used in a 73-d study to determine the effects of increasing sorghum DDGS in corn- or sorghum-based diets on pig growth performance, carcass characteristics, and fat characteristics. Pigs were allotted to 1 of 6 dietary treatments. These dietary treatments included: sorghum-based diets with sorghum DDGS included at 0, 15, 30, or 45%; a sorghum-based diet with 30% corn DDGS; and a corn-based diet with 30% corn DDGS (Tables 4, 5, and 6). There were 8 pigs per pen and 6 replications per treatment. Each pen provided 8 ft^2/pig and had totally slatted floors, one 5-hole self-feeder, and a cup waterer. Throughout the trial, the pigs had ad libitum access to feed and water. All treatment diets were in meal form and fed in 3 phases (d 0 to 28, d 28 to 56, and d 56 to 73). Pigs and feeders were weighed on d 0, d 28, d 56, and d 73 to determine ADG, ADFI, and F/G.

At the end of the study, the heaviest barrow and gilt were selected from every pen and taken to the K-State Meats Laboratory. Standard carcass characteristics were measured, as well as loin eye color, marbling and firmness, and fat color score. Fat samples from the 10^{th} rib were taken and analyzed for fatty acid profile and IV. The remaining pigs were taken to Triumph Foods LLC (St. Joseph, MO) for standard carcass data collection and jowl IV value.

[3] Urriola, P. E., D. Hoehler, C. Pederson, H. H. Stein, and G. C. Shurson. 2009. Amino acid digestibility of distillers dried grains with solubles produced from a sorghum- a sorghum-corn blend, and corn fed to pigs. J. Anim. Sci. 87:2574-2580.

Data were analyzed in a completely randomized design with pen as the experimental unit. Analysis of variance was used with the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC). Single degrees of freedom contrasts were used to make comparisons between: (1) the sorghum- and corn-based diet with 30% corn DDGS, (2) the sorghum diet with 30% sorghum DDGS vs. the corn-based diet with 30% corn DDGS, and (3) linear and quadratic effects of increasing sorghum DDGS (0, 15, 30, and 45%). Results were considered significant at $P \leq 0.05$ and considered a trend at $P \leq 0.10$.

Results and Discussion

Chemical Analyses. As expected, the corn and corn DDGS contained greater concentrations of linoleic acid (C18:2n-6) as well as lower monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) concentrations (Table 2). Sorghum and sorghum DDGS had greater concentrations of SFA and total *trans* fatty acids than the corn and corn DDGS. Therefore, this resulted in the corn and corn DDGS having greater IV than the sorghum and sorghum DDGS, respectively. As the amount of DDGS increased, bulk density of the diet decreased (Table 3).

Growth Performance. Overall (d 0 to 73), increasing DDGS (0, 15, 30, or 45%) decreased (linear, $P < 0.04$) ADG, ADFI, and final weight with no change in F/G (Table 7). Growth performance between pigs fed the corn- and sorghum-based diets with 30% corn DDGS was similar, as was the performance of pigs fed the sorghum-based diets with either sorghum or corn DDGS.

For carcass data of pigs taken to the Triumph packing plant, jowl IV increased (linear, $P < 0.01$) with increasing sorghum DDGS. Increasing sorghum DDGS decreased (linear ($P < 0.01$) backfat depth but had no effect on loin depth, resulting in increased (linear ($P < 0.01$) fat-free lean index (FFLI). Hot carcass weight decreased with increasing sorghum DDGS (linear ($P < 0.04$), but carcass yield was similar among treatments. Jowl IV tended ($P < 0.10$) to be greater in pigs fed the corn-based diet with 30% corn DDGS than those fed the sorghum-based diet with 30% corn DDGS. No other carcass characteristics were different among the sorghum or corn diets with corn DDGS. Pigs fed sorghum-based diets with 30% sorghum DDGS had decreased ($P < 0.04$) jowl IV than pigs fed the sorghum-based diets with 30% corn DDGS or pigs fed the corn-based diet with 30% corn DDGS.

For carcass data of pigs slaughtered at the K-State Meat Laboratory, increasing sorghum DDGS had no effect on HCW, carcass yield, purge loss, or drip loss; however, pH tended ($P < 0.06$) to increase with increasing DDGS (Table 8). Increasing sorghum DDGS had no effect on backfat thickness, 10th rib loin eye area, color, firmness, or marbling. Increasing sorghum DDGS decreased 10th rib loin redness (a*; linear, $P < 0.03$) and also tended to decrease the degree of yellowness (b*; linear, $P < 0.06$). For backfat samples collected at the 10th rib, the degree of redness (a*) decreased (linear, $P < 0.01$) and yellowness (b*) tended to decrease (linear, $P < 0.06$) as sorghum DDGS increased. Pigs fed the corn-based diet with 30% corn DDGS had a decreased degree of yellowness (b*; $P < 0.03$) compared with pigs fed the sorghum-based diet with 30% sorghum DDGS.

Carcass characteristics were not different among pigs fed sorghum- or corn-based diets with 30% corn DDGS or for pigs fed sorghum-based diets with either corn or sorghum DDGS. Pigs fed the sorghum diet with 30% corn DDGS tended to have loins that were firmer and had more marbling ($P < 0.08$) than those fed the corn diet with 30% corn DDGS.

Pigs fed sorghum with 30% sorghum DDGS had fat color that was more white (L*) and less yellow (b*) in color than pigs fed sorghum with 30% corn DDGS ($P < 0.03$; Table 8). Because a growing percentage of U.S. pork is exported to other international markets, sorghum DDGS may have an important role in the future of swine diets due to its ability to produce pork fat that is lighter in color and less yellow.

Carcass Fatty Acid Composition. Increasing sorghum DDGS reduced (linear, $P < 0.01$) palmitic (C16:0), stearic (C18:0), and oleic (C18:1 *cis*-9) fatty acids. On the other hand, linoleic (C18:2n-6) and linolenic (C18:3n-3) concentrations increased (linear, $P < 0.01$). As a result, SFA and MUFA decreased (linear, $P < 0.01$) and PUFA and backfat IV increased (linear, $P < 0.01$) as sorghum DDGS increased in the diet.

For backfat, pigs fed the corn-based diet with 30% corn DDGS had greater concentrations ($P < 0.05$) of C18:1 *cis*-9 and MUFA than pigs fed the sorghum-based diet with 30% corn DDGS (Table 9). Pigs fed the corn-based diet with 30% corn DDGS had decreased concentrations ($P < 0.03$) of C14:0, C16:0, C18:3n-3, and total *trans* fatty acids than pigs fed the sorghum-based diet with 30% sorghum DDGS. Pigs fed diets with corn DDGS had greater concentrations ($P < 0.01$) of C18:1 *cis*-9, C18:1n-7, and MUFA, whereas pigs fed diets with sorghum DDGS had greater concentrations ($P < 0.01$) of C18:2n-6, C20:2, and PUFA than pigs fed diets with corn DDGS.

Overall, pigs fed DDGS had greater ($P < 0.01$) IV than those fed the sorghum basal diet, with pigs fed corn DDGS having greater IV than those fed sorghum DDGS. Although the corn DDGS contained greater concentrations of UFA, the sorghum DDGS had greater concentrations of SFA. The results found in this study agree with previous research conducted on the effect of DDGS on carcass fat composition (Benz et al., 2011[4]).

In conclusion, we observed similar ADG, ADFI, and F/G, as well as carcass characteristics, for pigs fed corn- or sorghum-based diets with 30% DDGS. Backfat IV was greater in pigs fed increasing DDGS, with a notable increase in pigs fed corn DDGS compared with those fed sorghum DDGS. Feeding sorghum DDGS produces pork fat that is lighter in color and less yellow than those fed corn DDGS, which may have be important in pork export markets.

[4] Benz, J. M., M. D. Tokach, S. S. Dritz, J. L. Nelssen, J. M DeRouchey, R. C. Sulabo, and R. D. Goodband. 2011. Effects of dietary iodine value product on growth performance and carcass fat quality of finishing pigs. J. Anim. Sci. 89:1419-1428.

Table 1: Analyzed nutrient composition of ingredients (as-fed basis)[1]

Item	Sorghum	Corn	Sorghum DDGS[2]	Corn DDGS
DM, %	86.12	86.22	89.64	89.00
CP, %	8.24	7.39	29.04	25.70
Crude fat, %	2.07	2.36	7.17	8.71
Crude fiber, %	1.74	1.72	5.28	5.62
Ash, %	1.29	1.31	4.24	4.23
Amino acids, %				
Cysteine	0.13	0.14	0.44	0.43
Isoleucine	0.28	0.22	1.04	0.88
Leucine	0.95	0.76	2.94	2.65
Lysine	0.21	0.22	0.73	0.86
Methionine	0.12	0.13	0.39	0.47
Threonine	0.24	0.22	0.85	0.87
Tryptophan	0.06	0.05	0.15	0.18
Valine	0.37	0.32	1.34	1.21

[1] Values represent the mean of 1 composite sample. Diets were prepared using the analyzed values.
[2] Dried distillers grains with solubles.

Table 2. Fatty acid analysis of dietary ingredients

Item	Corn	Sorghum	Corn DDGS[1]	Sorghum DDGS
Myristic acid (C14:0), %	0.11	0.07	0.08	0.09
Palmitic acid (C16:0), %	16.30	14.35	15.02	16.82
Palmitoleic acid (C16:1), %	0.63	0.01	0.34	0.57
Margaric acid (C17:0), %	0.16	0.16	0.13	0.13
Stearic acid (C18:0), %	1.71	2.25	2.13	1.84
Oleic acid (C18:1 *cis*-9), %	26.36	22.42	26.25	27.57
Vaccenic acid (C18:1n-7), %	2.10	1.06	1.44	1.99
Linoleic acid (C18:2n-6), %	55.77	47.33	50.86	46.70
α-Linolenic acid (C18:3n-3), %	2.55	1.52	1.91	2.41
Arachidic acid (C20:0), %	0.25	0.63	0.41	0.27
Gadoleic acid (C20:1), %	0.29	0.23	0.26	0.27
Eicosadienoic acid (C20:2), %	0.10	0.10	0.09	0.09
Arachidonic acid (C20:4n-6), %	0.12	0.06	0.06	0.08
Other fatty acids, %	1.98	1.36	1.03	1.17
Total SFA, %[2]	17.94	19.08	18.32	19.69
Total MUFA, %[3]	23.81	29.48	28.34	30.48
Total PUFA, %[4]	57.49	50.19	52.95	49.33
Total *trans* fatty acids, % [5]	1.52	2.55	1.98	2.53
UFA:SFA ratio[6]	4.85	4.18	4.44	4.05
PUFA:SFA ratio[7]	3.20	2.63	2.89	2.51
Iodine value, g/100g[8]	121	114	118	114

[1] Dried distillers grains with solubles.
[2] Total SFA = ([C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C17:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]); brackets indicate concentration.
[3] Total MUFA = ([C14:1] + [C16:1] + [C18:1 *cis*-9] + [C18:1n-7] + [C20:1] + [C24:1]); brackets indicate concentration.
[4] Total PUFA = ([C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:2] + [C20:4n-6]); brackets indicate concentration.
[5] Total *trans* fatty acids = ([C18:1 *trans*] + [C18:2 *trans*] + [C18:3 *trans*]); brackets indicate concentration.
[6] UFA: SFA = (total MUFA + total PUFA)/total SFA.
[7] PUFA: SFA = total PUFA/total SFA.
[8] Calculated as IV value (IV) = [C16:1] × 0.95 + [C18:1] × 0.86 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C22:1] × 0.723; brackets indicate concentration.

Table 3. Bulk densities of experimental diets (as-fed basis) [1]

	Grain source					
	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn
	DDGS[2] source and level, %					
Item	None 0	Sorghum 15	Sorghum 30	Sorghum 45	Corn 30	Corn 30
Bulk density, lb/bushel[3]						
Phase 1	51.1	46.3	45.4	43.1	46.2	44.8
Phase 2	50.8	49.0	48.1	45.5	47.1	46.5
Phase 3	52.0	49.5	48.3	46.1	47.2	46.3

[1] Bulk densities represent the mass per unit volume. Diet samples were taken from the tops of feeders during each phase.
[2] Dried distillers grains with solubles.
[3] Phase 1 was d 0 to 28; Phase 2 was d 28 to 56; Phase 3 was d 56 to 73.

Table 4. Phase 1 diet composition (as-fed basis)[1]

	Grain source					
	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn
	DDGS[2] source and level, %					
Item	None 0%	Sorghum 15%	Sorghum 30%	Sorghum 45%	Corn 30%	Corn 30%
Ingredient, %						
Sorghum	76.20	63.10	50.20	36.90	51.05	17.25
Soybean meal (46.5% CP)	20.85	19.25	17.45	15.85	16.50	17.25
Corn	---	---	---	---	---	50.30
Sorghum DDGS	---	15.00	30.00	45.00		---
Corn DDGS	---	---	---	---	30.00	30.00
Monocalcium P (21% P)	0.90	0.55	0.20	---	0.25	0.30
Limestone	0.90	1.03	1.15	1.30	1.20	1.20
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
L-Lysine HCl	0.31	0.31	0.31	---	0.31	0.29
DL-Methionine	0.12	0.08	0.04	---	0.01	---
L-Threonine	0.08	0.04	0.01	---	0.02	0.02
Total	100	100	100	100	100	100
Calculated analysis						
Standardized ileal digestible amino acids, %						
Lysine	0.94	0.94	0.94	0.94	0.94	0.94
Isoleucine:lysine	62	68	73	79	68	67
Methionine:lysine	35	33	31	29	29	30
Met & Cys:lysine	58	58	58	58	58	59
Threonine:lysine	60	60	60	64	60	60
Tryptophan:lysine	17	17	17	17	17	17
Valine:lysine	70	78	86	94	81	80
Total lysine, %	1.03	1.06	1.09	1.12	1.11	1.11
CP, %	17.1	19.3	21.4	23.5	20.8	20.7
ME kcal/lb	1,484	1,457	1,430	1,400	1,488	1,505
Ca, %	0.60	0.59	0.58	0.60	0.58	0.59
P, %	0.55	0.54	0.53	0.55	0.53	0.54
Available P, %	0.27	0.27	0.27	0.31	0.27	0.27

[1] Diets were fed in meal form from d 0 to 28 of the experiment.
[2] Dried distillers grains with solubles.

Table 5. Phase 2 diet composition (as-fed basis)[1]

	Grain source					
	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn
	DDGS[2] source and level, %					
Item	None 0%	Sorghum 15%	Sorghum 30%	Sorghum 45%	Corn 30%	Corn 30%
Ingredient, %						
Sorghum	79.85	66.80	53.75	40.45	54.80	---
Soybean meal (46.5% CP)	17.30	15.70	14.05	12.30	12.95	13.85
Corn	---	---	---	---	---	53.90
Sorghum DDGS	---	15.00	30.00	45.00	---	---
Corn DDGS	---	---	---	---	30.00	30.00
Monocalcium P (21% P)	0.85	0.48	0.10	---	0.15	0.20
Limestone	0.90	1.03	1.15	1.30	1.18	1.15
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
L-Lysine HCl	0.29	0.28	0.28	0.28	0.28	0.26
DL-Methionine	0.09	0.05	0.01	---	---	---
L-Threonine	0.07	0.03	---	---	---	---
Total	100	100	100	100	100	100
Calculated analysis						
Standardized ileal digestible amino acids, %						
Lysine	0.83	0.83	0.83	0.83	0.83	0.83
Isoleucine:lysine	64	70	76	82	70	68
Methionine:lysine	34	31	29	30	30	32
Met & Cys:lysine	58	58	58	61	60	63
Threonine:lysine	60	60	62	66	61	61
Tryptophan:lysine	17	17	17	17	17	17
Valine:lysine	73	81	90	99	85	84
Total lysine, %	0.91	0.94	0.97	1.00	0.99	1.00
CP, %	15.8	17.9	20.1	22.2	19.5	19.4
ME kcal/lb	1,484	1,457	1,430	1,399	1,489	1,508
Ca, %	0.58	0.56	0.55	0.59	0.54	0.55
P, %	0.53	0.51	0.50	0.54	0.49	0.50
Available P, %	0.25	0.25	0.25	0.30	0.25	0.25

[1] Diets were fed in meal form from d 28 to 56 of the experiment.
[2] Dried distillers grains with solubles.

Table 6. Phase 3 diet composition (as-fed basis)[1]

	Grain source					
	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn
	DDGS[2] source and level, %					
Item	None 0%	Sorghum 15%	Sorghum 30%	Sorghum 45%	Corn 30%	Corn 30%
Ingredient, %						
Sorghum	83.35	70.30	57.25	43.80	58.20	---
Soybean meal (46.5% CP)	13.55	11.90	10.25	8.55	9.20	10.10
Corn	---	---	---	---	---	57.30
Sorghum DDGS	---	15.00	30.00	45.00	---	---
Corn DDGS	---	---	---	---	30.00	30.00
Monocalcium P (21% P)	0.75	0.40	0.05	---	0.10	0.15
Limestone	0.88	1.00	1.13	1.30	1.18	1.15
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.13	0.13	0.13	0.13	0.13	0.13
Trace mineral premix	0.13	0.13	0.13	0.13	0.13	0.13
L-Lysine HCl	0.26	0.25	0.25	0.25	0.26	0.23
DL-Methionine	0.07	0.03	---	---	---	---
L-Threonine	0.06	0.02	0.02	0.01	---	---
Chromic oxide	0.50	0.50	0.50	0.50	0.50	0.50
Total	100	100	100	100	100	100
Calculated analysis						
Standardized ileal digestible amino acids, %						
Lysine	0.71	0.71	0.71	0.71	0.71	0.71
Isoleucine:lysine	65	73	80	87	73	71
Methionine:lysine	33	31	30	33	33	34
Met & Cys:lysine	58	58	60	66	65	66
Threonine:lysine	62	62	67	70	63	63
Tryptophan:lysine	17	17	17	17	17	17
Valine:lysine	76	86	96	106	90	89
Total lysine, %	0.78	0.81	0.84	0.87	0.86	0.87
CP, %	14.3	16.4	18.6	20.7	18.0	17.9
ME kcal/lb	1,478	1,451	1,424	1,392	1,482	1,502
Ca, %	0.54	0.53	0.52	0.58	0.52	0.53
P, %	0.49	0.48	0.47	0.52	0.47	0.47
Available P, %	0.23	0.23	0.23	0.30	0.23	0.23

[1]Diets were fed in meal form from d 56 to 73 of the experiment.
[2]Dried distillers grains with solubles.

Table 7. Effect of sorghum dried distillers grains with solubles (DDGS) on finishing pig growth performance and carcass characteristics[1,2]

	Treatments							Probability, $P <$				
	A	B	C	D	E	F						
	Grain source											
	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn						
	DDGS source and level, %											
	None 0%	Sorghum 15%	Sorghum 30%	Sorghum 45%	Corn 30%	Corn 30%	SED	Linear DDGS[3]	Quadratic DDGS[3]	Corn vs. sorghum[4]	Corn DDGS vs. sorghum DDGS[5]	30% Sorghum DDGS vs. 30% corn DDGS[6]
Initial wt, lb	129.4	129.4	129.8	129.6	129.4	129.7	3.38	0.94	0.96	0.94	0.91	0.98
d 0 to 73												
ADG, lb	2.31	2.25	2.19	2.18	2.26	2.25	0.05	0.01	0.53	0.88	0.19	0.88
ADFI, lb	7.00	6.91	6.73	6.78	6.74	6.71	0.13	0.04	0.40	0.77	0.89	0.99
F/G	3.04	3.07	3.07	3.11	2.99	2.98	0.06	0.25	0.96	0.89	0.15	0.93
Final wt, lb	296.7	292.2	287.4	285.6	293.8	291.8	5.64	0.04	0.74	0.73	0.26	0.43
Carcass characteristics[2]												
Jowl iodine value[7]	69.6	71.2	72.1	74.7	73.8	75.2	0.93	0.01	0.40	0.10	0.04	0.01
Backfat, in.[7]	1.03	0.95	0.92	0.90	0.91	0.89	0.04	0.01	0.23	0.54	0.81	0.35
Loin depth, in.[7]	2.34	2.32	2.28	2.28	2.34	2.35	0.09	0.44	0.84	0.90	0.39	0.29
FFLI, %[7,8]	48.8	49.5	49.8	50.0	49.9	50.1	0.38	0.01	0.22	0.54	0.82	0.36
HCW, lb	213.8	208.6	206.1	201.8	208.0	208.1	0.60	0.04	0.96	0.99	0.70	0.67
Carcass yield, %[9]	71.40	71.41	71.74	71.79	71.45	71.43	0.60	0.43	0.96	0.97	0.81	0.77

[1] A total of 288 pigs were used in the 73-d trial with 36 pens and 6 replications per diet.
[2] Values are the means of 6 pigs per pen and 6 pens per treatment collected at the Triumph Foods LLC packing plant, St. Joseph, MO.
[3] Contrasts compare only sorghum-based diets.
[4] Sorghum with 30% corn DDGS vs. corn with 30% corn DDGS (treatment E vs. treatment F).
[5] Sorghum with 30% sorghum DDGS vs. sorghum with 30% corn DDGS (treatment C vs. treatment E).
[6] Sorghum with 30% sorghum DDGS vs. corn with 30% corn DDGS (treatment C vs. treatment F).
[7] Carcass characteristics adjusted using HCW as a covariate.
[8] FFLI (fat-free lean index)=50.767+ (0.035 × HCW, lb) - (8.979 × BF, in.).
[9] Yield percentage was calculated by dividing HCW by live weight (before transport to the packing plant, Triumph Foods, LLC, St. Joseph, MO).

Table 8. Effect of sorghum dried distillers grains with solubles (DDGS) on finishing pig carcass measurements[1]

	Treatments											
	A	B	C	D	E	F						
	Grain source							Probability, $P <$				
	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn						
	DDGS source and level, %											
Carcass measurments[2]	None 0%	Sorghum 15%	Sorghum 30%	Sorghum 45%	Corn 30%	Corn 30%	SED	Linear DDGS[4]	Quadratic DDGS[4]	Corn vs. sorghum[5]	Corn DDGS vs. sorghum DDGS[6]	30% Sorghum DDGS vs. 30% corn DDGS[7]
Live wt, lb	297.8	300.8	294.8	303.8	299.0	302.2	8.98	0.68	0.64	0.73	0.65	0.42
HCW, lb	224.5	225.2	220.3	224.2	222.8	220.9	5.42	0.74	0.68	0.74	0.65	0.91
Carcass yield, %	74.05	74.45	74.74	74.29	73.78	74.61	0.58	0.87	0.62	0.18	0.81	0.83
Purge loss, %	4.14	3.84	4.07	4.54	4.52	4.77	0.82	0.58	0.51	0.76	0.59	0.40
Drip loss, %	3.14	3.31	3.24	3.00	2.89	2.92	0.33	0.34	0.62	0.94	0.30	0.33
pH	5.61	5.63	5.65	5.65	5.65	5.65	0.02	0.06	0.39	0.83	0.77	0.94
Backfat												
1st rib, in.[2]	1.72	1.66	1.68	1.60	1.60	1.69	0.07	0.14	0.84	0.23	0.28	0.90
10th rib, in.[2]	0.97	1.07	1.01	0.91	0.99	0.95	0.10	0.47	0.14	0.68	0.76	0.47
Last rib, in.[2]	1.09	1.03	0.99	1.06	1.06	1.01	0.09	0.64	0.31	0.57	0.43	0.82
Last lumbar, in.[2]	0.77	0.85	0.83	0.77	0.81	0.84	0.05	0.96	0.06	0.45	0.66	0.75
10th rib loin characteristics												
Loin muscle area, sq. in.[2]	8.03	7.72	7.56	8.22	7.58	8.07	0.35	0.72	0.05	0.16	0.96	0.15
Color	2.38	2.08	2.21	2.21	2.04	2.17	0.24	0.62	0.39	0.60	0.49	0.86
Firmness	1.50	1.25	1.50	1.67	1.50	1.08	0.22	0.29	0.19	0.07	1.00	0.07
Marbling	1.25	1.17	1.25	1.21	1.33	1.08	0.14	0.92	0.83	0.08	0.55	0.23

continued

Table 8. Effect of sorghum dried distillers grains with solubles (DDGS) on finishing pig carcass measurements[1]

	Treatments											
	A	B	C	D	E	F						
	Grain source							Probability, $P <$				
	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn						
	DDGS source and level, %											
Carcass measurments[2]	None 0%	Sorghum 15%	Sorghum 30%	Sorghum 45%	Corn 30%	Corn 30%	SED	Linear DDGS[4]	Quadratic DDGS[4]	Corn vs. sorghum[5]	Corn DDGS vs. sorghum DDGS[6]	30% Sorghum DDGS vs. 30% corn DDGS[7]
Loin eye color[3]												
L*	59.88	59.91	60.25	59.44	60.18	58.41	1.01	0.76	0.56	0.09	0.94	0.08
a*	10.92	10.84	10.76	10.09	10.69	10.09	0.36	0.03	0.26	0.11	0.84	0.07
b*	16.69	16.52	16.68	15.88	16.45	15.83	0.37	0.06	0.23	0.10	0.53	0.03
Fat color[3]												
L*	84.79	85.40	85.66	85.42	83.93	84.90	0.70	0.34	0.40	0.18	0.02	0.29
a*	3.33	3.40	2.97	2.39	3.24	2.67	0.31	0.01	0.15	0.08	0.40	0.34
b*	11.14	11.05	10.90	10.60	11.55	10.63	0.29	0.06	0.61	0.01	0.03	0.36

[1] Values represent the mean of 6 observations (1 barrow and 1gilt) per treatment.
[2] Carcass characteristics adjusted using HCW as a covariate.
[3] CIE L* on a scale of 0-100 (0=black; 100=white); CIE a* is the degree of redness; CIE b* is the degree of yellowness.
[4] Contrasts compare only sorghum-based diets.
[5] Sorghum with 30% corn DDGS vs. corn with 30% corn DDGS (treatment E vs. treatment F).
[6] Sorghum with 30% sorghum DDGS vs. sorghum with 30% corn DDGS (treatment C vs. treatment E).
[7] Sorghum with 30% sorghum DDGS vs. corn with 30% corn DDGS (treatment C vs. treatment F).

Table 9. Effect of sorghum dried distillers grains with solubles (DDGS) on backfat fatty acid analysis[1]

	Treatments											
	A	B	C	D	E	F						
	Grain source							Probability, $P <$				
	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn						
	DDGS source and level, %											
	None 0%	Sorghum 15%	Sorghum 30%	Sorghum 45%	Corn 30%	Corn 30%	SED	Linear DDGS[2]	Quadratic DDGS[2]	Corn vs. sorghum[3]	Corn DDGS vs. sorghum DDGS[4]	30% Sorghum DDGS vs. 30% corn DDGS[5]
Myristic acid (C14:0), %	1.45	1.41	1.37	1.31	1.34	1.28	0.04	0.01	0.81	0.12	0.45	
Palmitic acid (C16:0), %	25.17	24.83	23.87	22.77	23.22	22.90	0.42	0.01	0.22	0.45	0.14	
Palmitoleic acid (C16:1), %	2.33	2.26	1.96	1.93	1.87	1.84	0.11	0.01	0.83	0.76	0.43	0.27
Margaric acid (C17:0), %	0.50	0.48	0.56	0.54	0.58	0.49	0.04	0.14	0.99	0.04	0.61	0.12
Stearic acid (C18:0), %	13.51	13.11	12.68	11.67	12.21	12.08	0.50	0.01	0.40	0.80	0.35	0.24
Oleic acid (C18:1 *cis*-9), %	40.68	39.91	38.30	37.53	36.19	37.42	0.53	0.01	1.00	0.03	0.01	0.10
Vaccenic acid (C18:1n-7), %	3.37	3.23	3.00	3.00	2.73	2.76	0.09	0.01	0.28	0.67	0.01	0.01
Linoleic acid (C18:2n-6), %	9.39	10.99	14.24	17.04	17.76	17.20	0.57	0.01	0.24	0.45	0.01	0.01
α-Linolenic acid (C18:3n-3), %	0.56	0.60	0.74	0.84	0.71	0.64	0.73	0.01	0.21	0.10	0.53	0.03
Arachidic acid (C20:0), %	0.27	0.28	0.26	0.24	0.25	0.26	0.04	0.07	0.23	0.76	0.76	1.00
Gadoleic acid (C20:1), %	0.85	0.89	0.82	0.49	0.76	0.81	0.01	0.10	0.22	0.27	0.15	0.74
Eicosadienoic acid (C20:2), %	0.53	0.61	0.73	0.82	0.85	0.88	0.04	0.01	0.81	0.55	0.01	0.01
Arachidonic acid (C20:4n-6), %	0.10	0.11	0.12	0.13	0.11	0.10	0.01	0.01	0.50	0.34	0.46	0.09
Other fatty acids, %	1.29	1.29	1.35	1.69	1.42	1.34	0.06	0.05	0.89	0.23	0.49	0.60
Total SFA, %[6]	41.12	40.32	38.93	36.74	37.82	37.22	0.78	0.01	0.21	0.44	0.16	0.04
Total MUFA, %[7]	47.31	46.39	44.17	43.34	41.63	42.91	0.63	0.01	0.92	0.05	0.01	0.05

continued

Table 9. Effect of sorghum dried distillers grains with solubles (DDGS) on backfat fatty acid analysis[1]

	Treatments											
	A	B	C	D	E	F						
	Grain source							Probability, $P <$				
	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn						
	DDGS source and level, %											
	None 0%	Sorghum 15%	Sorghum 30%	Sorghum 45%	Corn 30%	Corn 30%	SED	Linear DDGS[2]	Quadratic DDGS[2]	Corn vs. sorghum[3]	Corn DDGS vs. sorghum DDGS[4]	30% Sorghum DDGS vs. 30% corn DDGS[5]
Total PUFA, %[8]	10.55	12.24	15.74	18.77	19.38	18.77	0.80	0.01	0.20	0.45	0.01	0.01
Total *trans* fatty acids, %[9]	0.80	0.85	0.99	1.07	0.95	0.87	0.05	0.01	0.68	0.09	0.46	0.02
UFA:SFA ratio[10]	1.41	1.45	1.54	1.69	1.61	1.66	0.05	0.01	0.18	0.46	0.15	0.03
PUFA:SFA ratio[11]	0.26	0.30	0.40	0.51	0.51	0.50	0.03	0.01	0.16	0.73	0.01	0.01
Iodine value, g/100g[12]	58.66	60.72	64.78	69.23	68.66	68.61	1.23	0.01	0.12	0.93	0.01	0.01

[1] All values are on a DM basis.
[2] Contrasts compare only sorghum-based diets.
[3] Sorghum with 30% corn DDGS vs. corn with 30% corn DDGS (treatment E vs. treatment F).
[4] Sorghum with 30% sorghum DDGS vs. sorghum with 30% corn DDGS (treatment C vs. treatment E).
[5] Sorghum with 30% sorghum DDGS vs. corn with 30% corn DDGS (treatment C vs. treatment F).
[6] Total SFA = ([C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C17:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]); brackets indicate concentration.
[7] Total MUFA = ([C14:1] + [C16:1] + [C18:1 cis-9] + [C18:1n-7] + [C20:1] + [C24:1]); brackets indicate concentration.
[8] Total PUFA = ([C18:2n-6] + [C18:3n-3] + [C18:3n-6] + [C20:2] + [C20:4n-6]); brackets indicate concentration.
[9] Total *trans* fatty acids = ([C18:1 trans] + [C18:2 trans] + [C18:3 trans]); brackets indicate concentration.
[10] UFA: SFA = (total MUFA + total PUFA)/total SFA.
[11] PUFA: SFA = total PUFA/total SFA.
[12] Calculated as IV value (IV) = [C16:1] × 0.95 + [C18:1] × 0.86 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C22:1] × 0.723; brackets indicate concentration.