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Optimizing use of distillers grains in finishing diets containing steam-flaked corn[1]

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ABSTRACT: Two hundred ninety-nine crossbred yearling steers (363 ± 15 kg initial BW) were fed for an average of 114 d in a finishing study comparing 7 diets in which steam-flaked corn was used as the principal energy source. Forty-nine pens were used in this study with 7 BW blocks, 7 pens per treatment, and 5 to 7 steers per pen. A control diet with no distillers grains with solubles (DGS) was compared with 6 diets containing 15% DGS (DM basis). The diets contained wet sorghum DGS with 0 or 6% alfalfa hay, dried sorghum DGS with 0 or 6% alfalfa hay, wet corn DGS with 6% alfalfa hay, or dried corn DGS with 6% alfalfa hay. Apparent total tract digestibilities were calculated by total collection of fecal material from the concrete-surfaced pens over a 72-h period. Dry matter intake, ADG, G:F, and carcass characteristics were similar ($P \geq 0.18$) for steers fed finishing diets with or without 15% DGS. However, apparent total tract digestibilities of DM and OM were 2.8% less ($P \leq 0.03$) for finishing diets containing 15% DGS (DM basis). Dry matter intake, ADG, G:F, apparent total tract digestibility, and carcass characteristics were not different ($P \geq 0.09$) for steers fed finishing diets containing sorghum or corn DGS. Dry matter intake, ADG, G:F, apparent total tract digestibility, and carcass characteristics also were not different ($P \geq 0.10$) for steers fed finishing diets containing wet or dried DGS. Steers fed sorghum DGS with 6% hay consumed more DM ($P < 0.01$) and gained more BW ($P < 0.01$) than steers fed diets without hay, but G:F were not different ($P > 0.78$). Sorghum DGS diets containing alfalfa hay were 4% less ($P = 0.01$) digestible than sorghum DGS diets containing no hay. Carcasses of steers fed sorghum DGS diets without hay were lighter, leaner, and had decreased USDA yield grades ($P = 0.01$) compared with steers fed sorghum DGS diets containing hay. Feeding moderate levels (i.e., 15%, DM basis) of DGS resulted in growth performance and carcass characteristics similar to those of cattle fed no DGS. In addition, sorghum- and corn-based DGS had similar feeding values, and wet (≈31% DM) and dried (≈91% DM) DGS also had similar feeding values. Complete removal of alfalfa hay in diets containing DGS improved diet digestibility but reduced growth performance and carcass finish.

Key words: cattle, corn, digestibility, distillers grain, sorghum

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INTRODUCTION

Distillers grains with solubles (**DGS**) are the predominant by-product produced during fermentation of grains to fuel ethanol and contain bran (high in fiber), germ (high in fat), and the protein of cereals used for fermentation. Given the relatively high fiber content of DGS, it is conceivable that DGS could serve as a replacement for roughages in finishing diets. Feeding roughages stimulates saliva production and helps maintain ruminal motility and digestive health in feedlot cattle (Balch, 1958; Rumsey et al., 1970; Sissons et al., 1984). Replacing roughages with DGS would be advantageous because roughages have relatively low digestibility, are prone to high shrink loss, and are relatively expensive per unit of energy. A major expense incurred with production of DGS is the energy needed to dehydrate by-products to acceptable moisture levels (Rausch and Belyea, 2006). Moisture content is critically important because it directly affects transportation costs, storage characteristics, and handling properties of the feed. Dehydration of by-products may also alter nutritive value of DGS (Rasco et al., 1989). Generally speaking, extensive heating can result in formation of indigestible com-

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Table 1. Nutrient composition of distillers grains with solubles (DGS) fed to finishing heifers

	Sorghum DGS		Corn DGS	
Nutrient, % (DM basis)	Dried	Wet	Dried	Wet
DM				
Karl-Fisher, n = 1	—	41	—	33
Oven DM[1]	92 ± 1.6	36 ± 2.0	90 ± 1.2	30 ± 1.7
CP[1]	45 ± 1.2	34 ± 0.8	33 ± 0.4	36 ± 0.7
NDF[1]	31 ± 2.3	20 ± 1.6	38 ± 2.5	29 ± 1.8
Crude fat[1]	7 ± 0.3	11 ± 0.4	10 ± 0.4	15 ± 0.4
Phosphorus[1]	0.48 ± 0.02	1.09 ± 0.08	0.50 ± 0.01	0.94 ± 0.07
Potassium[1]	0.35 ± 0.01	1.41 ± 0.05	0.52 ± 0.01	1.08 ± 0.04

[1]n = 12.

plexes between carbohydrates and proteins, potentially reducing energy availability and efficiency of nitrogen utilization; moreover, volatile energy compounds can be lost with drying. Consequently, there is significant potential for creating differences in nutritional value of DGS as a result of drying. Corn and sorghum are the predominate grains used for ethanol production in the United States, and the use of each is largely determined by geographical location of the ethanol plant (e.g., high plains or corn belt region). In some regions, both corn and sorghum DGS may be available; however, relatively few data are available pertaining to comparative nutritional values of DGS derived from corn and sorghum. Objectives of this study were to compare 1) sorghum-based with corn-based DGS, 2) wet DGS with dried DGS, and 3) performance of cattle fed diets containing DGS with and without added roughage.

MATERIALS AND METHODS

Care and handling of animals used in this study were conducted under the approval of the Kansas State University Institutional Animal Care and Use Committee.

Two hundred ninety-nine crossbred yearling steers (363 ± 15 kg initial BW) were obtained from a common source and used in a randomized complete block study. Steers were fed finishing diets based on steam-flaked corn and 6% alfalfa hay (DM basis). Whole corn was steam flaked to a bulk density of 360 g/L with a mean geometric particle size of 5,724 ± 601 μm (n = 159) and starch availability of 50 ± 4 (n = 52). Starch availability was determined by incubating 25 g of whole flakes in 100 mL of a 2.5% amyloglucosidase enzyme solution (wt/vol) for 15 min and reading the percentage of solubles on a refractometer (Sindt et al., 2006). Experimental diets were formulated to compare a finishing diet with no DGS to 6 diets containing 15% DGS (DM basis). Weekly samples of feedstuffs were collected throughout the duration of the study for DM and nutrient content determination. Dry matter for wet distillers grains was determined by Karl Fisher titration (AquaStar Model V1B, EM Science, Gibbstown, NJ), with all other ingredients dried at 105°C for 16 h in a forced-air oven. Crude protein was determined using Leco FP-2000 nitrogen analyzer (Leco Corporation, St. Joseph, MI). Lipid content was determined using Goldfisch ether extraction method. Chemical compositions of DGS fed in this study are summarized in Table 1. The source of DGS was sorghum or corn and was in the dried (i.e., dehydrated; ≈91% DM) or wet (≈31% DM) form. In addition to source (i.e., sorghum vs. corn) and form (i.e., dried vs. wet) of DGS, alfalfa hay was fed at 0 or 6% (DM basis) in the finishing diets containing dried sorghum DGS and wet sorghum DGS, respectively. Diets (Table 2) were formulated to contain 14% CP; however, after analyzing the weekly ingredient samples, CP levels varied slightly among treatments. All DGS fed in this study were received at 1 time before the start of the study. Sorghum DGS were received from an ethanol plant in Colwich, KS, and corn DGS were received from an ethanol plant located in York, NE. Wet DGS were stored in large plastic silage bags. Dried DGS were stored in a covered commodity shed.

On arrival at the feedlot, steers were offered ad libitum access to long-stemmed prairie hay and fresh water. Two days after arrival and 39 d before study initiation, cattle were uniquely identified with numbered tags in both ears and vaccinated for bovine rhinotracheitis-parainfluenza3 and clostridials using Bovishield-4 and Fortress-7 vaccines (Pfizer Animal Health, Exton, PA), and Micotil-300 (0.03 mL/kg of BW, Elanco Animal Health, Indianapolis, IN). Seven days later steers were revaccinated with Bovishield-4 (Pfizer Animal Health), topically dosed with Phoenectin pour-on (Phoenix Scientific Inc., St. Joseph, MO), and implanted with Revalor IS (80 mg of trenbolone acetate + 16 mg of estradiol; Intervet Inc., Millsboro, DE). On d −39, steers were individually weighed, stratified by BW, blocked by BW, and assigned randomly to pens. On d 0, pens of steers were weighed, and treatments were assigned randomly to pen. Each BW block contained all 7 treatments. Forty-nine pens were used in this study with 7 BW blocks, 7 pens per treatment, and 5 to 7 steers per pen.

Before initiation of the study, steers were allowed ad libitum access to each of 4 adaptation diets leading to

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Table 2. Composition of steam-flaked corn based finishing diets containing sorghum or corn distillers grains with solubles (DGS) fed to yearling steers

		Dried sorghum DGS		Wet sorghum DGS		Corn DGS (6% hay)	
Item	Control	0% Hay	6% Hay	0% Hay	6% Hay	Dried	Wet
Ingredient, %							
Steam-flaked corn	81.0	75.2	69.8	73.9	68.4	69.6	71.5
DGS	—	15.0	15.0	16.1	16.3	15.1	12.8
Concentrated separator by-product	5.1	5.0	5.1	5.0	5.0	5.1	5.2
Alfalfa hay	5.9	—	5.9	—	5.8	5.9	6.0
Limestone	1.3	1.7	1.4	1.6	1.4	1.3	1.4
Soybean meal	2.9	—	—	—	—	—	—
Urea	1.0	—	—	0.4	0.2	0.2	0.2
Vitamin/mineral premix[1]	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Supplement[2]	2.5	2.7	2.4	2.6	2.5	2.4	2.5
Analyzed composition, %							
DM	81.6	82.4	82.7	67.2	67.4	82.5	66.5
CP	13.7	13.9	14.6	13.9	13.8	13.5	13.3
Calculated DIP,[3] %	3.8	4.5	4.4	5.1	5.0	4.9	5.2
Crude fat	3.8	4.5	4.4	5.1	5.0	4.9	5.2
Calcium	0.52	0.61	0.62	0.62	0.65	0.57	0.68
Phosphorus	0.24	0.26	0.26	0.36	0.36	0.26	0.31
Potassium	0.92	0.78	0.87	0.95	1.04	0.89	0.97

[1]Formulated to provide the following per kilogram of dietary DM: 0.1 mg of Co; 10 mg of Cu; 0.6 mg of I; 60 mg of Mn; 0.2 mg of Se; 60 mg of Zn; and 1,200 IU of vitamin A.

[2]Fed at 0.23 kg/d (DM basis) to provide 300 mg of monensin (Elanco Animal Health, Indianapolis, IN) and 90 mg of tylosin (Elanco Animal Health) daily.

[3]DIP = degradable intake protein.

control diet described in Table 2. Adaptation diets were fed for 5 d, with a portion of alfalfa hay replaced with steam-flaked corn at each step. Adaptation and finish rations were delivered once daily at 1400 h. Residual feed in bunk was observed each day at approximately 2 h before feeding. Feed deliveries were adjusted each day so that only trace amounts of residual feed were left in bunk. On d 0, steers were switched from control diet to respective treatments (Table 2). Pens were concrete-surfaced (36 m^2) with overhead shade covering the bunk and one-half the pen. Pens included automatic water fountains and 3.2 m of bunk space. Individual pens of steers were weighed immediately before shipping to a commercial abattoir to obtain BW. Body weights were taken approximately 17 h after last feed delivery. Final BW was calculated by dividing BW by 0.96 (i.e., assuming a 4% shrink).

Apparent Total Tract Diet Digestibility

Apparent DM digestibilities were determined for the 3 lightest BW blocks over a 72-h period according to procedures described by Löest et al. (2001). Briefly, on d 116 of the finishing period, steers were removed from their pens at 0800 h, pen surfaces were thoroughly cleaned, and all unconsumed feed was removed from feed bunks. Steers were returned to their pens and fed their daily ration. After 24, 48, and 72 h, all feces were collected from each pen, weighed, thoroughly homogenized, and a representative sample (≈2%) was collected. Daily samples from each pen were composited, thoroughly homogenized, and frozen until later analysis. Daily feed refusals (if any) also were collected for each of the sampling days. Diet samples, feed refusals, and feces were analyzed for DM and OM content. Apparent DM and OM digestibility were calculated as [1 − (fecal DM output/DMI)] × 100% and [1 − (fecal OM output/OMI)] × 100%, respectively.

Steers were slaughtered in 2 groups based on BW blocks. On d 101 (4 pens/treatment) and d 129 (3 pens/treatment), steers were shipped 182 km to a commercial abattoir in Emporia, KS, at which time carcass data were collected by trained personnel from Kansas State University. Carcass weight and incidence of liver abscesses were obtained at the time of slaughter. Longissimus muscle area, subcutaneous fat thickness over 12th rib, and percentage KPH were obtained after a 24-h chill. In addition, marbling score, quality grades, and yield grades were acquired from USDA grading service personnel. Final BW was calculated by dividing carcass weight by a common dressing yield of 63.5%. Actual dressing yield was calculated by HCW/(0.96 × final BW).

Statistical Analysis

Growth performance, apparent total tract digestibility, and carcass characteristics were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC). Pen was the experimental unit, and block was used as a random effect. Contrasts were used to compare 1) control diet with the average of the 4 diets containing DGS and 6% alfalfa hay, 2) average of the wet and dried sorghum DGS with hay to the average of dried and wet corn

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DGS, 3) average of wet corn DGS and wet sorghum DGS with and without hay with the mean of dried corn DGS and dried sorghum DGS with and without hay, and 4) average of the wet and dried sorghum DGS with hay with the average of wet and dried sorghum DGS without hay.

RESULTS AND DISCUSSION

Control vs. DGS

Growth performance, apparent total tract digestibility, and carcass characteristics of steers fed steam-flaked corn finishing diets with no DGS compared with diets containing alfalfa hay and wet and dried DGS derived from corn and sorghum grains are shown as contrast 1 in Tables 3, 4, and 5, respectively. Dry matter intake, ADG, and G:F were not different ($P \geq 0.33$) for yearling steers fed steam-flaked corn finishing diets with or without DGS. Vasconcelos et al. (2007) and Depenbusch et al. (2008a,b) observed similar effects on DMI when cattle were fed finishing diets with or without DGS. Larson et al. (1993), Ham et al. (1994), and Al-Suwaiegh et al. (2002) all reported improvements in ADG and G:F when up to 30% of DGS was added to dry-rolled corn-based finishing diets. Research by Vander Pol et al. (2006b) suggests that ADG and G:F is optimized between 30 to 40% wet corn DGS in finishing diets based on dry-rolled corn; however, Daubert et al. (2005) reported that ADG and G:F were optimized between 8 and 16% wet sorghum DGS when fed to yearling heifers consuming a finishing diet based on steam-flaked corn. However, Vasconcelos et al. (2007) observed a linear decrease in ADG and G:F when graded levels (i.e., 0, 5, 10, and 15%, respectively) of wet sorghum DGS were fed in steam-flaked corn-based diets. Depenbusch et al. (2008a) observed no difference in ADG and G:F when a portion of steam-flaked corn was replaced with 13% dried corn DGS. However, in a second study, Depenbusch et al. (2008b) observed a 7% decrease in ADG and G:F when a portion of steam-flaked corn was replaced with 25% wet corn DGS.

Research from our lab (Daubert et al., 2005) suggests that G:F increases to an optimal upper threshold in SFC diets and then declines with additional levels of distillers grains in feedlot diets. Daubert et al. (2005) suggest the optimal upper threshold in SFC diets is near 15% (DM basis). However in more recent studies, when distillers grains were fed near threshold (Depenbusch et al., 2008a), G:F was not different from diets containing no distillers grains. When wet corn distillers grains were fed above threshold (i.e., 25.5% DM basis), Depenbusch et al. (2008b) observed a significant reduction in G:F. However, Black et al. (2008) and Uwituze et al. (2008a) reported no difference when a portion of the steam-flaked corn was replaced with 25% dried corn distillers grains. In the current study, DGS was fed near the estimated threshold and resulted in animal performance similar to steers fed no DGS. Depenbusch et al. (2008a) proposed that differences in ruminal variables (i.e., rumen pH and passage rate) and fermentation characteristics between dry-rolled and steam-flaked corn may affect the feeding value of DGS.

Apparent total tract digestibilities of DM and OM were 2.8% less ($P \leq 0.03$) for steers fed steam-flaked corn diets containing 15% DGS compared with steers fed no DGS. May et al. (2008) and Uwituze et al. (2008b) observed a 2.8 and 7.2% reduction, respectively, in apparent total tract digestibility for DM when 25% DGS was included in finishing diets based on steam-flaked corn. They observed a 3.1 and 7.2% reduction, respectively, in apparent total tract digestibility for OM when 25% DGS was fed. Likewise, Corrigan et al. (2008) observed a 5.3 and 5.6% reduction in apparent total tract digestibility for DM and OM, respectively, when 40% wet DGS was fed in dry-rolled, high-moisture, and steam-flaked corn based finishing diets. Reductions in DM and OM digestibility are likely due to production processes at the ethanol plants resulting in variable nutrient content of DGS. However, digestibility of DGS may also be affected by ruminal variables such as pH, which are affected by grain type, grain processing, roughage level, and roughage source.

Carcass weight, LM area, KPH, and subcutaneous fat over 12th rib were not different (Table 4; $P \geq 0.18$) for yearling steers fed finishing diets with or without DGS. These results are supported by those of Larson et al. (1993), Lodge et al. (1997), and Depenbusch et al. (2008a). However, in a recent study by Corrigan et al. (2007), carcass weight increased linearly as dry-rolled corn and urea was replaced with wet DGS (i.e., 0, 15, 27.5, and 40% wet DGS, respectively). In addition, 12th-rib fat responded quadratically to wet DGS with the fattest carcasses appearing at 27.5% wet DGS. Likewise, Benson et al. (2005) observed a linear increase in carcass weight and 12th-rib fat thickness when dried DGS replaced 0, 15, 25, or 35% of cracked corn and urea. However, when Corrigan et al. (2007) replaced steam-flaked corn and urea with wet DGS, they observed a quadratic effect on carcass weight and 12th-rib fat thickness in steers with the heaviest and fattest carcasses appearing when 15% wet DGS was fed. Depenbusch et al. (2008b) observed a 3.5% reduction in carcass weight and a 3.2% reduction in LM area when 25% wet corn DGS was fed in a steam-flaked corn diet. In the current study, steers fed no DGS had a greater dressing percentage than steers fed DGS. Observed differences in dressing percentage are similar to those observed by Depenbusch et al. (2008b).

Marbling score, USDA yield grade, and USDA quality grade were not different (Table 5; $P \geq 0.10$) for yearling steers fed finishing diets with or without DGS. Research by Daubert et al. (2005) showed that increasing wet sorghum DGS from 0 to 40% of diet DM linearly increased USDA yield grade while linearly decreasing marbling score. Similarly, Vasconcelos et al. (2007) reported a linear increase in yield grade with graded levels of wet sorghum DGS (0, 5, 10, and 15%, respectively).

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Table 3. Animal growth performance of yearling steers fed steam-flaked corn based finishing diets containing sorghum or corn distillers grains with solubles (DGS)

		Dried sorghum DGS		Wet sorghum DGS		Corn DGS (6% Hay)			Contrast[1]			
Item	Control	0% Hay	6% Hay	0% Hay	6% Hay	Dried	Wet	SEM	1	2	3	4
No. of pens (steers)	7 (43)	7 (43)	7 (41)	7 (43)	7 (42)	7 (44)	7 (43)	—			—	—
Days on feed	115	115	115	115	115	115	115	—			—	—
Initial BW, kg	364	362	364	364	365	359	363	14.7	0.61	0.24	0.32	0.69
Final BW, kg	543	522	550	533	543	542	538	12.0	0.92	0.19	0.99	0.01
DMI, kg/d	9.34	8.66	9.57	8.71	9.39	9.48	9.21	0.27	0.64	0.22	0.13	0.01
ADG, kg	1.42	1.25	1.47	1.33	1.41	1.44	1.38	0.05	0.82	0.52	0.64	0.01
G:F, g/kg	151	145	154	152	150	152	151	3.7	0.92	0.85	0.75	0.27
Carcass-adjusted performance												
Final BW,[2] kg	524	499	522	514	518	521	520	11.2	0.47	0.94	0.37	0.01
ADG, kg	1.44	1.22	1.41	1.35	1.37	1.45	1.41	0.05	0.49	0.43	0.61	0.01
G:F, g/kg	154	142	148	155	147	153	153	4.0	0.33	0.12	0.14	0.78
Apparent total tract digestibility, %												
DM	83.8	83.9	82.6	86.4	80.1	81.2	82.0	0.90	0.03	0.79	0.74	0.01
OM	86.8	86.4	85.2	89.0	83.4	84.0	85.0	0.85	0.02	0.79	0.39	0.01

[1]Preplanned orthogonal contrast: 1 = control vs. DGS (control vs. dried sorghum DGS with hay, wet sorghum DGS with hay, dried corn DGS, and wet corn DGS). 2 = sorghum DGS vs. corn DGS (dried sorghum DGS with hay and wet sorghum DGS with hay vs. dried corn DGS and wet corn DGS). 3 = wet DGS vs. dried DGS (wet sorghum DGS with hay, wet sorghum DGS without hay, and wet corn DGS vs. dried sorghum DGS with hay, dried sorghum DGS without hay, and dried corn DGS). 4 = sorghum DGS with hay vs. sorghum DGS without hay (dried sorghum DGS with hay and wet sorghum DGS with hay vs. dried sorghum DGS without hay and wet sorghum DGS without hay).

[2]Carcass adjusted final BW calculated by dividing HCW by a common dressing yield of 63.5%.

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Table 4. Carcass characteristics of yearling steers fed steam-flaked corn based finishing diets containing sorghum or corn distillers grains with solubles (DGS)

		Dried sorghum DGS		Wet sorghum DGS		Corn DGS (6% hay)			Contrast[1]			
Item	Control	0% Hay	6% Hay	0% Hay	6% Hay	Dried	Wet	SEM	1	2	3	4
HCW, kg	333	317	332	327	329	331	330	7.09	0.47	0.94	0.37	0.01
Dress yield, %	63.9	63.2	62.8	63.9	63.1	63.6	63.9	0.25	0.03	0.01	0.01	0.01
LM area, cm^2	83.9	78.7	81.9	82.6	81.3	82.6	81.9	1.74	0.18	0.52	0.44	0.51
KPH, %	2.7	2.6	2.7	2.7	2.7	2.8	2.7	0.06	0.70	0.58	0.32	0.50
12th-rib fat, cm	1.14	1.09	1.27	1.07	1.19	1.12	1.25	0.08	0.35	0.46	0.92	0.03
Liver abscess, %	2.4	2.5	4.8	7.2	0.0	2.4	2.4	3.16	0.99	0.99	0.99	0.41

[1]Preplanned orthogonal contrast: 1 = control vs. DGS (control vs. dried sorghum DGS with hay, wet sorghum DGS with hay, dried corn DGS, and wet corn DGS). 2 = sorghum DGS vs. corn DGS (dried sorghum DGS with hay and wet sorghum DGS with hay vs. dried corn DGS and wet corn DGS). 3 = wet DGS vs. dried DGS (wet sorghum DGS with hay, wet sorghum DGS without hay, and wet corn DGS vs. dried sorghum DGS with hay, dried sorghum DGS without hay, and dried corn DGS). 4 = sorghum DGS with hay vs. sorghum DGS without hay (dried sorghum DGS with hay and wet sorghum DGS with hay vs. dried sorghum DGS without hay and wet sorghum DGS without hay).

Likewise, Mateo et al. (2004) and Benson et al. (2005) reported a linear increase in USDA yield grade but no difference in marbling score when dry-rolled corn and urea were replaced with 0, 15, 25, or 35% dried DGS or 0, 20, and 40% DGS, respectively. However, Depenbusch et al. (2008b) observed no difference in USDA yield grade and a 4.5% decrease in marbling score when 25% wet corn DGS was fed to yearling heifers.

Sorghum vs. Corn DGS

Growth performance and carcass characteristics of steers fed steam-flaked corn finishing diets with corn or sorghum DGS are shown as contrast 2 in Tables 3, 4, and 5, respectively. Dry matter intake, ADG, G:F, and apparent total tract digestibility were not different ($P \geq 0.12$) for yearling steers fed steam-flaked corn finishing diets containing sorghum or corn DGS. Only 2 studies (Al-Suwaiegh et al., 2002; Vasconcelos et al., 2007) have made direct comparisons between sorghum and corn DGS. Al-Suwaiegh et al. (2002) replaced a portion of dry-rolled corn with 30% DGS, and Vasconcelos et al. (2007) replaced a portion of steam-flaked corn with 10% DGS. Similar to our results, DMI, ADG, and G:F were not different in both studies between sorghum and corn DGS. However, in a review by Klopfenstein et al. (2008) they suggested that corn DGS was superior to sorghum DGS.

Carcass weight, LM area, KPH, and subcutaneous fat over 12th rib were not different (Table 4; $P \geq 0.46$) for steers fed finishing diets with sorghum or corn DGS. Vasconcelos et al. (2007) noted a decrease in subcutaneous fat over 12th rib, whereas Al-Suwaiegh et al. (2002) reported a tendency for less subcutaneous fat over 12th rib for steers fed corn DGS.

Marbling score, USDA yield grade, and USDA quality grade were not different between treatments (Table 5; $P \geq 0.09$). Vasconcelos et al. (2007) reported a decrease in average USDA yield grade for steers fed 10% (DM basis) corn DGS but reported no differences in marbling score or USDA quality grade. Al-Suwaiegh et al. (2002) reported no differences in marbling score, USDA yield grade, or USDA quality grade.

Wet vs. Dried DGS

Growth performance and carcass characteristics of steers fed steam-flaked corn finishing diets with wet or dried DGS are shown as contrast 3 in Tables 3, 4, and 5, respectively. Dry matter intake, ADG, G:F, and apparent total tract digestibility were not different ($P \geq 0.13$) between wet and dried DGS. Mateo et al. (2004) reported a 3% decrease in DMI and 5% increase in G:F when a portion of dry-rolled corn was replaced with 20% wet DGS compared with dried DGS. In addition, Mateo et al. (2004) reported even greater differences (11 and 12% for DMI and G:F, respectively) when a portion of cracked corn was replaced with 40% wet DGS compared with dried DGS. Likewise, Ham et al. (1994) observed a 7% decrease in DMI and an 8% increase in G:F when 40% wet DGS replaced a portion of the dry-rolled corn compared with when dried DGS replaced a portion of dry-rolled corn. Furthermore, Klopfenstein et al. (2008) conducted a meta-analysis of their research and reported that G:F was maximized between 30 and 50% inclusion of wet DGS and between 10 and 20% for dried DGS. Klopfenstein et al. (2008) noted a similar trend for ADG. It is not clear why our results do not support those of Ham et al. (1994), Mateo et al. (2004), and Klopfenstein et al. (2008). It is plausible that we may have observed similar results if we had fed greater levels of DGS (i.e., >15%, DM basis). Mateo et al. (2004) and Klopfenstein et al. (2008) suggested that increases in G:F for wet DGS over dried DGS is greater at greater inclusion levels.

Carcass weight, LM area, KPH, and subcutaneous fat over 12th rib were not different (Table 4; $P \geq 0.32$) for steers fed finishing diets with wet or dried DGS. In addition, marbling score, USDA yield grade, and USDA quality grade were similar between treatments (Table 5; $P \geq 0.10$). These results are supported by Mateo et al. (2004), who observed similar carcass weights, LM area,

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Table 5. Carcass characteristics of yearling steers fed steam-flaked corn based finishing diets containing sorghum or corn distillers grains with solubles (DGS)

		Dried sorghum DGS		Wet sorghum DGS		Corn DGS (6% hay)			Contrast[1]			
Item	Control	0% Hay	6% Hay	0% Hay	6% Hay	Dried	Wet	SEM	1	2	3	4
USDA yield grade												
YG 1, %	13	4	7	14	4	4	5	0.04	0.10	0.76	0.47	0.42
YG 2, %	47	65	42	50	40	64	48	0.09	0.83	0.09	0.11	0.07
YG 3, %	38	26	46	34	53	30	40	0.08	0.65	0.09	0.19	0.02
YG 4, %	2	5	2	2	3	2	7	0.03	0.61	0.35	0.65	0.73
YG 5, %	—	—	3	—	—	—	—	0.01	0.56	0.19	0.29	0.19
Average	2.3	2.3	2.5	2.2	2.5	2.3	2.5	0.12	0.22	0.31	0.62	0.05
USDA quality grade, %												
Choice or greater	81	67	76	70	70	79	74	0.09	0.41	0.57	0.61	0.52
Select	19	33	24	28	30	21	24	0.09	0.46	0.46	0.83	0.64
Standard	—	—	—	2	—	—	2	0.01	0.65	0.31	0.10	0.31
Marbling score[2]	474	441	458	431	447	458	458	15.61	0.20	0.67	0.51	0.21

[1]Preplanned orthogonal contrast: 1 = control vs. DGS (control vs. dried sorghum DGS with hay, wet sorghum DGS with hay, dried corn DGS, and wet corn DGS). 2 = sorghum DGS vs. corn DGS (dried sorghum DGS with hay and wet sorghum DGS with hay vs. dried corn DGS and wet corn DGS). 3 = wet DGS vs. dried DGS (wet sorghum DGS with hay, wet sorghum DGS without hay, and wet corn DGS vs. dried sorghum DGS with hay, dried sorghum DGS without hay, and dried corn DGS). 4 = sorghum DGS with hay vs. sorghum DGS without hay (dried sorghum DGS with hay and wet sorghum DGS with hay vs. dried sorghum DGS without hay and wet sorghum DGS without hay).

[2]Marbling score: 400 = small, 500 = modest.

KPH, 12th-rib fat, yield grade, and marbling score for steers fed wet or dried DGS.

Sorghum DGS With or Without Hay

Growth performance and carcass characteristics of steers fed steam-flaked corn finishing diets with sorghum DGS containing 0 or 6% alfalfa hay are shown as contrast 4 in Tables 3, 4, and 5, respectively. Steers fed finishing diets containing no alfalfa hay consumed 8.3% less ($P = 0.01$) DM and gained BW 7.6% slower ($P = 0.01$) than steers fed alfalfa hay. In addition, the carcass adjusted final BW was 2.6% less ($P = 0.01$) for steers fed no alfalfa hay. However, G:F was not different ($P = 0.78$) between steers fed 0 or 6% alfalfa hay. Apparent total tract digestibility for DM and OM was 4.5 and 3.9% greater, respectively, for steers fed no alfalfa hay.

Several studies (Kreikemeier et al., 1990; Huffman et al., 1992) have documented animal performance improvement when roughages are added to finishing diets at low levels (i.e., 5 to 10%). However, Sindt et al. (2003) reported no differences in DMI, BW gain, or G:F when alfalfa hay was reduced from 6 to 2% of the diet DM in finishing diets based on steam-flaked corn and containing 25, 35, or 45% wet corn gluten feed. These results indicate that roughage levels may be reduced when feeding moderate levels of by-products such as DGS and gluten feed. Farran et al. (2006) reported a 7.5 and 6.0% reduction in DMI and ADG, respectively, when alfalfa hay was reduced from 7.5 to 0% when 0 or 35% wet corn gluten feed was fed. However, Farran et al. (2006) observed a tendency for alfalfa hay and wet corn gluten feed interaction. Steers fed no alfalfa hay and no wet corn gluten feed were the least efficient, whereas steers fed no alfalfa hay and 35% wet corn gluten were the most efficient. Our research supports that of Farran et al. (2006) that DMI and ADG are both decreased and G:F is similar when roughage is completely removed from diets with and without by-products.

Apparent total tract digestibility for DM and OM were reduced ($P = 0.01$) when 6% roughage was added to steam-flaked corn finishing diets. Replacing a portion of the highly digestible steam-flaked corn with the less digestible alfalfa hay is likely the main factor responsible for the observed reductions in digestibility.

Carcass weight was 2.6% less ($P = 0.01$), and 12th-rib fat thickness was 12% less ($P = 0.01$) for steers fed finishing diets containing no alfalfa hay than steers fed 6% (DM basis) alfalfa hay. In addition, average USDA yield grade was 10% less ($P = 0.05$) for steers fed finishing diets containing no alfalfa hay. Feeding no alfalfa hay resulted in more ($P = 0.07$) yield grade 2 carcasses, whereas feeding 6% alfalfa hay resulted in more ($P = 0.02$) yield grade 3 carcasses. Reduced carcass weight, 12th-rib fat, and yield grade is likely a direct result of the fact that the steers fed no alfalfa hay consumed less DM and gained less BW. However, USDA quality grade and marbling score were similar ($P \geq 0.21$) for

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steers fed 0 and 6% alfalfa hay. Dressing percentage was greater ($P = 0.01$) for steers fed no alfalfa hay compared with steers fed 6% alfalfa hay. These differences may be due to changes in digestive tract contents as a result of feeding alfalfa hay.

Ethanol production in the high plains states has increased in recent years. This has led to a wide variety of DGS available to feedlots including sorghum- or corn-based DGS and wet or dry DGS. Nutritional value of each of these products is thought to be different and influenced by grain type used and ethanol manufacturing processes. However, in our study we did not detect any differences between sorghum- and corn-based DGS or between wet and dry DGS when included in steam-flaked finishing diets at approximately 15% (DM basis). Therefore, other reasons such as availability of different types of DGS and distance from ethanol plant will be the primary drivers of which type of DGS is included into finishing diets. Complete removal of alfalfa hay from diets containing DGS will result in a reduction in DMI, ADG, and carcass weight. However, G:F is not different, whereas apparent total tract digestibility is increased when no alfalfa hay is added to finishing diets. Therefore, it may be possible for feedlot operators to decrease roughage inclusion levels when DGS is included into finishing diets based on steam-flaked corn.

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