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Dried distillers grains with solubles with reduced corn silage levels in beef finishing diets[1,2]

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ABSTRACT: Two finishing experiments were conducted to evaluate the use of 25% dried corn distillers grains with solubles (DDG) in beef cattle finishing diets by partially replacing a portion of the grain and soybean meal in the control diets. In Exp.1, crossbred heifers (n = 377; BW 378 ± 4.1 kg) were fed diets consisting of steam-flaked corn (SFC) with a control diet containing 0% DDG and 15% corn silage (CS), 25% DDG and 15% CS, or 25% DDG and 5% CS. Compared with the control treatment, heifers fed DDG and 15% CS had a greater proportion of USDA yield grade 4 and 5 carcasses ($P = 0.04$; 5.68 vs. 14.12), and smaller LM area ($P = 0.04$; 86.09 vs. 82.48 cm^2). In Exp. 2, crossbred heifers (n = 582; BW = 377 ± 27.09 kg) were fed diets similar to Exp. 1 except dry-rolled corn (DRC) and SFC were compared as the basal grain sources. Treatments included DRC or SFC: with control diets containing 0% DDG and 15% CS, 25% DDG and 15% CS, or 25% DDG and 5% CS. Feeding SFC decreased DMI ($P < 0.01$), improved G:F ($P < 0.01$) and final shrunk BW ($P = 0.05$) compared with DRC. Average USDA yield grade was greater for cattle fed DRC than for those fed SFC ($P = 0.02$), but calculated yield grade was not different among treatments ($P = 0.71$). Feeding DDG and 5% CS, regardless of grain source, led to decreased DMI and greater G:F than feeding DDG and 15% CS ($P = 0.02$). When comparing the control treatments with the diets containing 25% DDG and 15% CS shrunk final BW, ADG, and G:F were decreased ($P \leq 0.05$); however, carcass-adjusted measurements were not different ($P > 0.52$). Results indicate that roughage levels can be reduced in feedlot diets containing 25% DDG with no adverse effects on BW gain, feed efficiency, or carcass quality.

Key words: distillers grains, dry-rolled corn, feedlot, steam-flaked corn

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INTRODUCTION

Roughages are perceived as an essential component of feedlot diets because they help minimize the incidence of digestive disturbances. However, roughages are relatively expensive in relation to their nutritional value and digestibility in high-concentrate feedlot diets. Loerch and Fluharty (1998) evaluated diets containing high-moisture corn with 0 or 15% corn silage (**CS**) and found that G:F was greater for steers fed 0 vs. 15% CS. Firkins et al. (1985), Kreikemeier et al. (1990), and Loerch and Fluharty (1998) observed increases in the proportion of condemned livers in cattle fed feedlot diets with no roughage. Defoor et al. (2002) evaluated various roughage sources and found that roughages containing greater effective NDF may be fed at smaller percentages of the diet. Reducing roughage in feedlot diets has been one way to improve efficiency; however, the risks of increased frequency of liver abscesses and digestive disturbances must be considered.

Expansion of the ethanol industry into the Southern Great Plains has prompted research to determine the comparative value of distillers grains in beef finishing diets containing dry-rolled corn (**DRC**) and steam-flaked corn (**SFC**). Corrigan et al. (2009) observed a grain processing method by wet distillers grains interaction for many cattle performance measurements, whereby inclusion up to 40% wet distillers grains improved performance in DRC-based diets but decreased performance in SFC-based diets. Our objectives in these experiments were to evaluate performance and carcass characteristics of cattle fed DDG as a partial

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Table 1. Composition of steam-flaked-corn-based finishing diets with reduced corn silage levels and 25% corn dried distillers grains with solubles used in Exp. 1

	0% DDG[1]	25% DDG	25% DDG
Item, % of DM	15% Silage	15% Silage	5% Silage
Ingredient			
Steam-flaked corn	75.3	55.6	65.4
Corn silage	14.8	14.9	4.9
DDG	—	24.7	24.7
Soybean meal	4.3	—	—
Urea	1.2	0.2	0.3
Limestone	1.6	1.8	1.9
Supplement[2]	0.7	0.6	0.6
Feed additive premix[3]	2.1	2.2	2.2
Nutrient, %			
DM	68.8	69.7	79.8
CP	13.9	14.0	14.3
Calcium	0.7	0.7	0.7
Phosphorus	0.2	0.4	0.4
Ether extract	3.2	4.8	5.2
NDF	16.5	23.4	17.7

[1]Dried corn distillers grains with solubles.

[2]Formulated to provide 0.3% salt, 2,650 IU of vitamin A, 0.15 mg of Co, 10 mg of Cu, 0.5 mg of I, 0.3 mg of Se, 50 mg of Mn, and 50 mg of Zn per kilogram of diet DM.

[3]Feed additive premix provided 300 mg of monensin, 90 mg of tylosin (Elanco Animal Health, Greenfield, IN), and 0.5 mg of melengestrol acetate (Pfizer Animal Health, New York, NY) per animal daily in a ground corn carrier.

replacement for DRC or SFC, and to determine if CS could be reduced from 15 to 5% when DDG are added to the diets. We hypothesized that the NDF portion of the diet coming from the DDG is presumably greater in digestibility than the roughage it replaces and may improve feedlot performance.

MATERIALS AND METHODS

The studies were conducted in accordance with procedures approved by the Kansas State University Institutional Animal Care and Use Committee.

Exp. 1

Three hundred eighty-four *Bos taurus* crossbred heifers (384 ± 1.4 kg) were used in a completely random design finishing study. Dietary treatments were SFC (average flake density = 360 g/L) with no DDG and 15% CS (control; **CON**), SFC with 25% DDG and 15% CS (**HI**), and SFC with 25% DDG and 5% CS (**LO**). The DDG replaced a portion of the SFC in the diet in addition to soybean meal in the control diets. In the LO diets approximately 10% additional SFC replaced the CS in the HI diets. Samples of each feed ingredient were sampled weekly throughout experiment and analyzed for CP, ether extract, starch, Ca, and P. Dry matter for all ingredients was determined by drying samples at 105°C for 24 h in a forced-air oven. Crude protein was determined using a Leco FP-2000 nitrogen analyzer (Leco Corporation, St. Joseph, MI). Ether extract of feed ingredients were determined by the AOAC official method 920.39 (AOAC, 1995). Determination of NDF was conducted using an Ankom 200 Fiber Analyzer (Ankom Technologies, Macedon, NY) in accordance with procedures of Van Soest et al. (1991). When determining NDF in samples, heat-stable α-amylase (Ankom Technologies) was added to grain samples to remove any residual starch. Ingredient percentages and composition of finishing diets are presented in Table 1. Composition of DDG fed to heifers throughout the feeding experiment is presented in Table 2.

On arrival, heifers were identified with uniquely numbered tags in both ears, injected with a 7-way clostridial bacterin and 4-way viral vaccine (Fortress-7 and Bovishield-4, respectively; Pfizer Animal Health, Exton, PA), administered a topical parasiticide (Phoenectin pour-on, Phoenix Scientific Inc., St. Joseph, MO), and implanted with an estradiol/trenbolone acetate implant (Revalor 200; 200 mg of trenbalone acetate and 20 mg of estradiol; Intervet Inc., Millsboro, DE). Heifers were fed a receiving ration containing 40% roughage and 60% concentrate for 56 d and then transitioned to the control finishing diet over a period of 3 wk. Heifers

Table 2. Composition of dried corn distillers grains with solubles fed to feedlot heifers in Exp. 1 and 2 (all values except DM are on a DM basis)

Item, %	Exp. 1	Exp. 2
CP	28.8	29.4
Calcium	0.04	0.04
Phosphorus	0.8	0.9
NDF	33.5	34.7
Ether extract	9.8	9.7
DM	91.5	91.6

were fed this diet for 14 d before initiating experimental treatments to minimize differences in gastrointestinal tract fill. Heifers were housed in 24 soil-surfaced pens (245 m^2) with automatic water fountains and 9.4 m of bunk space. On d 1, cattle were individually weighed, stratified from lightest to heaviest BW (unshrunk), and randomly assigned within strata to 1 of 24 pens (15 or 16 heifers per pen; 8 pens per treatment); treatments were then randomly applied to experimental units (pens). Heifers were offered ad libitum access to diets delivered twice daily for 85 d. If there was residual feed present before feeding, or if feed became wet due to precipitation, orts were weighed, dried at 55°C for 2 d, and the dried weight was subtracted from total dry feed delivered to estimate actual DMI for the pen.

On d 85 of the feeding period, BW of each pen of cattle were determined immediately before shipping to a commercial abattoir in Emporia, KS. Carcass weights and incidence of liver abscesses were determined at harvest. After a 24-h chill, LM area, subcutaneous fat thickness over the 12th rib, KPH percentage, marbling score, and USDA quality grade were obtained. Marbling score, USDA yield grade, and quality grade were determined by USDA graders. Final adjusted BW was calculated as carcass weight divided by a common dressing percentage of 63.5% (base grid value). Yield grades are reported as the calculated values derived from individual carcass measurements (USDA, 1997) and as determined by a USDA grader.

Statistical Analysis

Growth performance and carcass characteristics were analyzed as a completely random design using the PROC GLM procedure (SAS Inst. Inc., Cary, NC). Pen was the experimental unit. The model statement included the effect of dietary treatment. There were 2 contrasts evaluated: 1) means of cattle fed the control diet compared with cattle fed 25% DDG and 15% CS, and 2) mean of cattle fed 25% DDG with 15% CS vs. cattle fed 25% DDG with 5% CS. Treatment means were calculated using the LSMEANS. Mean comparisons with P-values less than or equal to 0.05 were declared significant, and values less than or equal to 0.10 were considered tendencies.

Exp. 2

Five hundred eighty-two *Bos taurus* crossbred heifers (377 ± 0.4 kg) were used in a randomized complete block design in a 2 × 3 factorial treatment arrangement. Factors consisted of grain processing method (DRC vs. SFC) and level (15 vs. 5%) of CS in 25% DDG diets compared with a control diet with 15% CS and no DDG. Heifers were fed SFC (average flake density = 360 g/L) with 0% DDG and 15% CS, SFC with 25% DDG and 15% CS, SFC with 25% DDG and 5% CS, DRC with 0% DDG and 15% CS, DRC with 25% DDG and 15% CS, or DRC with 25% DDG and 5% CS. The DDG replaced a portion of the grain used in the control diets in addition to soybean meal. In the 25% DDG 5% CS diets approximately 10% additional grain replaced the CS in the 25% DDG 15% CS diets. Individual feedstuff sampling and nutrient composition were determined as described Exp. 1. Composition of the DDG fed to heifers throughout the feeding experiment is described in Table 2. Finishing diets and analyzed nutrient compositions are presented in Table 3.

Heifers were processed, vaccinated, and implanted as in Exp. 1. Heifers were fed a receiving ration containing 40% roughage and 60% concentrate and then transitioned to the control finishing diet over a period of 3 wk. Heifers were fed this diet for 14-d before initiating experimental treatments to minimize differences in gastrointestinal tract fill. Heifers were housed as described above. On d 1, cattle were individually weighed (unshrunk), stratified from lightest to heaviest BW and blocked by BW. Heifers were randomly assigned within block to 1 of 12 pens (12 pens per block; 21 to 24 heifers per pen; 4 pens per treatment). Heifers were offered ad libitum access to diets delivered once daily for 110 d. If there was substantial residual feed present before feeding, or if feed became wet from precipitation, orts were weighed and dried at 55°C for 2 d to estimate actual DMI for each pen. Final BW and carcass measurements were determined as described for Exp. 1.

Statistical Analyses

Growth performance and carcass characteristics were analyzed statistically using the MIXED procedure of SAS. Pen was the experimental unit. The model statement included the effects of dietary treatment. Block was used as a random effect, and treatment means were calculated using the LSMEANS option. There were 5 preplanned contrasts evaluated: 1) mean of cattle fed DRC vs. means of cattle fed SFC; 2) means of cattle fed diets containing 0% DDG and 15% CS compared with cattle fed 25% dried distillers grains and 15% CS; 3) mean of cattle fed 25% DDG with 15% CS vs. cattle fed 25% DDG with 5% CS; 4) grain processing method (DRC or SFC) by DDG interaction for cattle fed 15% CS; and 5) grain processing method (DRC or SFC) by roughage level (15 or 5% CS) interaction for diets containing DDG. Comparisons with P-values less than or equal to 0.05 were declared significant, and values less than or equal to 0.10 were considered tendencies.

RESULTS AND DISCUSSION

Exp. 1

We observed no differences in DMI when comparing cattle fed the LO ($P = 0.26$) diet to those fed the HI diet, or the CON to the HI diet ($P = 0.29$, Table 4). These results are similar to observations made by Depenbusch et al. (2009b), who fed diets containing 15

Table 3. Composition of steam-flaked or dry-rolled-corn-based finishing diets with reduced corn silage and 25% corn dried distillers grains with solubles used in Exp. 2

	Dry-rolled corn			Steam-flaked corn		
	0% DDG[1]	25% DDG	25% DDG	0% DDG	25% DDG	25% DDG
Item, % of DM	15% Silage	15% Silage	5% Silage	15% Silage	15% Silage	5% Silage
Ingredient						
Steam-flaked corn	—	—	—	74.1	56.5	65.7
Dry-rolled corn	74.3	56.7	65.8	—	—	—
Corn silage	13.3	13.3	4.4	13.4	13.4	4.4
DDG	—	25.4	25.1	—	25.5	25.2
Vegetable oil	2.2	—	—	2.2	—	—
Soybean meal	4.5	—	—	4.5	—	—
Urea	1.2	0.2	0.3	1.2	0.2	0.3
Limestone	1.6	1.7	1.7	1.7	1.7	1.7
Supplement[2]	0.7	0.5	0.5	0.7	0.5	0.5
Feed additive premix,[3] %	2.2	2.2	2.2	2.2	2.2	2.2
Nutrient, %						
DM	74.3	74.8	83.5	71.5	72.6	80.3
CP	15.4	15.3	15.5	14.7	14.9	14.9
Calcium	0.8	0.7	0.7	0.8	0.7	0.7
Phosphorus	0.3	0.4	0.4	0.3	0.4	0.4
Ether extract	5.8	5.3	5.4	5.8	5.3	5.4
NDF	15.4	22.7	17.5	15.5	22.7	17.6

[1]Dried corn distillers grains with solubles.

[2]Formulated to provide 0.3% salt, 2,650 IU of vitamin A, 0.15 mg of Co, 10 mg of Cu, 0.5 mg of I, 0.3 mg of Se, 50 mg of Mn, and 50 mg of Zn per kilogram of diet DM.

[3]Feed additive premix provided 300 mg of monensin, 90 mg of tylosin (Elanco Animal Health, Greenfield, IN), and 0.5 mg of melengestrol acetate (Pfizer Animal Health, New York, NY) per animal daily in a ground corn carrier.

to 75% DDG (DM) to feedlot heifers. They observed a quadratic effect on DMI, where DMI was similar among treatments up to 30% but decreased thereafter.

Final BW, carcass-adjusted final BW, carcass-adjusted ADG, carcass-adjusted G:F, and G:F were not affected by treatments ($P > 0.15$, Table 4). Ham et al. (1994) and Firkins et al. (1985) observed improvements in cattle performance when including DDG in finishing diets containing DRC. The basal grain in our study was SFC, and energy value of SFC is greater than that of DRC (Barajas and Zinn, 1998), and potentially nearer to that of DDG. Therefore, it is reasonable to expect that DDG would have a different value depending on the grain source that it is used to displace. Zinn et al. (1995) observed that ruminal pH in cattle that were limit-fed DRC had greater ruminal pH compared with cattle fed SFC (6.07 vs. 5.67, respectively). However, Corrigan et al. (2009) observed that differences in pH were relatively small for cattle fed DRC or SFC diets in ad libitum (5.43 vs. 5.52 for DRC and SFC, respectively). When pH is less than 6.4, NDF digestibility is decreased as a consequence of decreases in activity of fibrolytic bacteria in vitro (Calsamiglia et al., 2008); however, Krause and Combs (2003) used a ruminal pH of 5.8 in vivo. Decreases in ruminal pH when feeding SFC or DDG has been shown to occur at critical periods during fermentation and may further exacerbate this problem (May et al., 2009). Uwituze et al. (2008) incubated a 50:50 mixture of DRC and DDG for 6, 12, 24, or 48 h at pH 5.0, 5.5, or 6.0 and observed that IVDMD was markedly depressed with decreased pH. In studies reported by May et al. (2009), Uwituze et al. (2010), and Vander Pol et al. (2009), the addition of distillers grains to finishing diets has not been shown to impact the digestion of NDF as a proportion of NDF digested. Because of the decreased concentration of fiber in feedlot diets, current research estimating apparent total tract digestibility may be lacking; further describing site and extent of digestion may aid in our understanding of digestion of distillers grains.

In the present study, CON cattle had greater LM area than cattle fed the HI diet ($P = 0.04$; contrast 1, Table 4). The reason for this effect is not evident because carcass weights and final BW were similar among treatments. Decreases in LM area between control cattle and cattle fed 25% wet corn distillers grains with solubles are consistent with observations made by Depenbusch et al. (2008). However, contrary to the present study, those authors noted decreased HCW for cattle fed 25% wet corn distillers grains vs. control cattle.

Mean yield grade, as determined by USDA graders, was not different among treatments, but the proportion of heifers with yield grade 4 and 5 was greater for HI cattle than the CON treatment ($P = 0.04$; contrast 1, Table 4). The impact of DDG on carcass yield grades are consistent with observations by Depenbusch et al. (2009a), who noted increases in carcass fatness with increased amounts of DDG in the diet.

Marbling score, USDA quality grade, subcutaneous fat over the 12th rib, and KPH percentage were not affected by decreasing roughage or by including DDG in finishing diets ($P > 0.14$, Table 4). There were no

Table 4. Feedlot performance and carcass characteristics for yearling heifers fed steam-flaked-corn-based finishing diets containing corn dried distillers grains with solubles in Exp. 1

	0% DDG[1]	25% DDG	25% DDG		Contrast[2]	
Item	15% Silage	15% Silage	5% Silage	SEM	1	2
No. of pens (heifers)	8 (127)	8 (124)	8 (126)	—	—	—
Initial BW, kg	379	377	377	4.07	0.75	0.98
Final BW,[3] kg	493	487	485	4.51	0.31	0.62
Carcass-adjusted final BW,[4] kg	491	487	486	5.02	0.50	0.91
DMI, kg/d	9.01	8.77	8.52	0.16	0.29	0.26
ADG,[3] kg/d	1.34	1.30	1.26	0.04	0.28	0.45
Carcass-adjusted ADG,[4] kg/d	1.32	1.29	1.28	0 04	0.53	0.83
G:F[3]	0.149	0.148	0.148	0.003	0.76	0.93
Carcass-adjusted G:F[4]	0.146	0.148	0.151	0.003	0.80	0.51
HCW, kg	312	309	309	3.18	0.50	0.90
Dressed yield, %	63.23	63.46	63.73	0.16	0.36	0.28
USDA quality grade						
Prime, %	0.78	0.00	0.00	0.45	0.23	1.00
Choice, %	55.11	62.24	61.93	4.29	0.22	0.96
Select, %	40.10	37.76	36.46	3.61	0.68	0.82
Standard, %	2.39	0.00	0.78	1.12	0.13	0.61
Dark cutter, %	0.83	0.00	0.83	0.68	0.40	0.40
Calculated yield grade	2.67	2.90	2.72	0.09	0.10	0.20
USDA yield grade[5]	2.62	2.74	2.66	0.07	0.38	0.40
Yield grade 1,[5] %	2.40	1.56	1.62	1.02	0.59	0.97
Yield grade 2,[5] %	39.27	36.35	39.11	4.86	0.64	0.66
Yield grade 3,[5] %	53.49	47.92	48.18	5.32	0.41	0.97
Yield grade 4 and 5,[5] %	5.68	14.12	11.09	3.13	0.04	0.45
Marbling score[6]	517	505	503	8.95	0.33	0.89
KPH, %	2.24	2.28	2.27	0.04	0 42	0.84
12th rib fat, cm	1.40	1.46	1.41	0.05	0.40	0.48
LM area, cm^2	86.09	82.48	84.85	1.00	0.04	0.16
Liver abscess, %	1.62	3.96	6.30	1.75	0.32	0.32

[1]Corn dry distillers grains with solubles.

[2]Contrast 1: Mean of diets with 0% dried distillers grains and 15% silage vs. mean of diets containing 25% dried distillers and 15% silage. Contrast 2: Mean of dried distillers grains diets with 15% silage vs. mean of dried distillers grains diets with 5% silage.

[3]Final BW, ADG, and G:F were calculated using final shrunk BW (4% shrink).

[4]Final BW, ADG, and G:F were computed by using carcass-adjusted final BW. Final BW = HCW divided by a dressing percentage of 63.5 (base grid value).

[5]Yield grade as determined by a USDA grader.

[6]Marbling score 500 = Small.

differences in cattle performance or carcass measurements when comparing the HI treatment with the LO treatment ($P > 16$; contrast 2, Table 4).

Exp. 2

Vegetable oil was added to the control diet such that lipid levels were similar across all treatments. The authors wanted to assure that if differences in cattle performance were to be observed, these differences were not due to differences in lipid content of each respective diet. Interestingly, lipid content did not appear to affect cattle performance because similar responses were observed in SFC treatments in Exp. 1 (not balanced for fat) and SFC treatments in Exp. 2.

No significant grain processing method × DDG interactions were detected among treatments that included 15% CS ($P > 0.18$; contrast 4, Table 5). The lack of interactions between grain processing and distillers grains is supported by observations of Leibovich et al. (2009), who reported no significant interaction when 15% sorghum wet distillers grains with solubles were fed with SFC or DRC-based diets. Corrigan et al. (2009) fed SFC, DRC, or high-moisture corn with 0, 15, 27.5, or 40% wet corn distillers grains with solubles and observed a grain processing × distillers grain interaction for ADG and G:F. Increasing the dietary concentration of distillers grains in diets with DRC or high-moisture corn improved ADG and G:F, but adding distillers grains to diets with SFC yielded no improvements in performance. The lack of interaction observed in the current study compared with Corrigan et al. (2009) may be in part due to the source of the distillers grains (wet vs. dry) and the smaller amount utilized in the current study compared with the greater inclusion levels (up to 40%) in Corrigan et al. (2009). Likewise, the reduced concentration of sorghum wet distillers grains utilized in the Leibovich et al. (2009) experiment may explain the lack of interaction between grain source and distillers grains. In the current experiment when comparing DRC and SFC diets, improvements in BW gain efficiency due to flaking were 13.0, 9.9, and 9.9% for the control, DDG with 15% CS, and DDG with 5% CS treatments, respectively. When weighted to reflect differences in grain content of the diets, these differences equate to improvements of 15.1 to 17.6% greater G:F due to flaking, which is comparable with the improvements reported by Zinn et al. (2002).

There were no grain processing method × roughage level interactions with the diets containing DDG for feedlot performance or carcass characteristics ($P >$ 0.07; contrast 5, Table 5). There was a tendency for an interaction ($P = 0.07$) observed on USDA yield grade 1 carcasses. Proportions of yield grade 1 carcasses for cattle fed DRC 15% CS, DRC 5% CS, SFC 15% CS, and SFC 5% CS were 4.17, 7.43, 11.82, and 5.64%, respectively. The reason for the observed tendency for an interaction is not evident.

There was a decrease in DMI when feeding SFC vs. DRC (7.61 vs. 8.18 kg/d, respectively; $P < 0.01$; contrast 1, Table 5) with no effect on carcass-adjusted ADG ($P = 0.12$), which corresponded with an increase in carcass-adjusted G:F (0.159 vs. 0.143, respectively; $P < 0.01$). Final shrunk BW was greater for cattle fed SFC vs. DRC ($P = 0.05$, contrast 1, Table 5). When calculating ADG from shrunk final BW, there was a tendency ($P = 0.08$, contrast 1, Table 5) for greater ADG when feeding SFC vs. DRC. Likewise, there was an improvement in G:F ($P < 0.01$, contrast 1, Table 5) when comparing SFC with DRC using the shrunk final BW. Feeding SFC tended to increase HCW compared with feeding DRC-based diets (324 vs. 321 kg, respectively; $P = 0.08$; contrast 1, Table 5). Our results are similar to findings of Corona et al. (2005), Owens et al. (1997), and Zinn et al. (1998), who reported improvements in G:F, decreases in DMI, and variable effects on ADG when comparing SFC with DRC in feedlot diets.

Mean USDA yield grade, as determined by a USDA grader, was greater for heifers fed DRC-based diets than heifers fed SFC-based diets (2.62 vs. 2.51, respectively; $P = 0.05$; contrast 1, Table 5), but calculated yield grades were not affected by grain processing method ($P = 0.71$). True causes for differences between graded yield grades and calculated yield grades are not evident. Interestingly, there was a numeric increase in marbling score ($P = 0.11$; contrast 1, Table 5) for cattle fed SFC compared with their counterparts fed DRC (529 vs. 519, respectively). Huck et al. (1998) observed that cattle fed SFC had greater marbling scores than their DRC-fed counterparts; however, contrary to our results Owens and Gardner (2000) found that cattle fed DRC had a greater marbling score than cattle fed SFC (524 vs. 482) in their meta-analysis of 552 published trials.

When comparing the control diets with the diets containing 25% DDG and 15% CS, we observed that final shrunk weights were greater for control cattle than cattle fed DDG ($P = 0.05$, contrast 2, Table 5). Moreover, ADG and G:F using final shrunk BW were greater for control cattle than cattle fed DDG ($P = 0.02$, contrast 2, Table 5). However, when comparing these same measurements in a carcass-adjusted manner, there were no differences among treatments ($P > 0.52$, contrast 2, Table 5). Similar observations were made by Uwituze et al. (2010), whereby shrunk final BW, ADG, and G:F were greater in control cattle compared with cattle fed 25% DDG, but when calculating carcass-adjusted measurements the authors found no differences.

Adding DDG to diets containing 15% CS compared with the control treatments increased dressing percentage ($P = 0.04$; contrast 2, Table 5). Moreover, dressing percentage was greater in heifers fed DDG and 5% CS compared with heifers fed the DDG and 15% CS ($P <$ 0.01; contrast 3, Table 5). These differences are likely attributable to differences in digestive tract fill as was also noted by Depenbusch et al. (2009a).

Though overall incidence was small (3 carcasses), the percentage of USDA Standard carcasses was greater for cattle fed diets containing 15% CS and no DDG compared with diets with DDG and 15% CS ($P = 0.03$; contrast 2, Table 5). No differences were detected among treatments with respect to the proportions of carcasses that graded USDA Prime or Choice ($P > 0.11$; Table 5). These results are similar to those of Roeber et al. (2005), who noted that feeding distillers grains up to 25% of diet DM did not affect carcass quality grade in Holstein cattle. Moreover, marbling score, KPH percentage, fat thickness over the 12th rib, and LM area were not different among treatments ($P > 0.22$; Table 5).

When CS was decreased from 15 to 5% in the DDG diets, DMI was decreased regardless of grain source (P < 0.01; contrast 3, Table 5). These results are similar to those observed in Exp. 1. In addition, G:F was increased when a portion of the CS was removed from diets containing DDG with either grain source ($P = 0.02$; contrast 3, Table 5). Similar findings were reported by Stock et al. (1990), Loerch (1991), and Loerch and Fluharty (1998), who observed reductions in DMI and improvements in G:F when removing a portion or all of the dietary roughage from feedlot cattle diets. Adding DDG to diets or decreasing a portion of the roughage when DDG were fed did not affect ADG ($P > 0.52$).

Defoor et al. (2002) noted that the use of roughage sources with greater NDF concentrations made it possible to include less dietary concentrations of roughage with no deleterious effects on animal performance. In both of our experiments, partial removal of CS decreased DMI, but had no effect on BW gain. In Exp. 2, this resulted in greater G:F in cattle fed DDG diets observed in Exp. 2 and numerical improvements in Exp. 1. Vasconcelos and Galyean (2007) observed that average roughage inclusion level from the Texas Tech University Feedlot Consultant survey was 8.30% in summer months and 9.00% in winter months. Uwituze et al. (2010) fed diets containing 0 or 25% corn DDG with alfalfa hay (6%) or CS (10%) in SFC-based diets with no effects on DMI, ADG, or G:F. Roughage amounts commonly fed in feedlot diets may be above the quantity needed to optimize cattle performance when feeding DDG. It is conceivable that the 15% CS levels used in the current studies were above the optimal range.

Table 5. Feedlot performance and carcass characteristics of yearling heifers fed steam-flaked or dry-rolled-corn-based finishing diets containing corn dried distillers grains with solubles in Exp. 2

	Dry-rolled corn			Steam-flaked corn				Contrast[1]				
	0% DDG[2]	25% DDG	25% DDG	0% DDG	25% DDG	25% DDG						
Item	15% Silage	15% Silage	5% Silage	15% Silage	15% Silage	5% Silage	SEM	1	2	3	4	5
No. of pens (heifers)	4 (93)	4 (95)	4 (94)	4 (94)	4 (91)	4 (94)	—	—	—	—	—	
Initial BW, kg	377	377	377	377	378	378	27.09	0.11	0.09	0.36	0.62	0.44
Final BW,[3] kg	505	501	494	517	505	494	27.06	0.05	0.02	0.01	0.25	0.53
Carcass-adjusted final BW,[3] kg	503	507	505	515	509	508	28.11	0.08	0.64	0.82	0.20	0.94
DMI, kg/d	8.37	8.38	7.78	8.08	7.70	7.15	0.99	<0.01	0.19	<0.01	0.18	0.88
ADG,[3] kg/d	1.17	1.12	1.06	1.27	1.16	1.06	0.03	0.08	0.02	0.02	0.24	0.48
Carcass-adjusted ADG,[4] kg/d	1.15	1.17	1.17	1.26	1.19	1.19	0.08	0.12	0.52	0.92	0.18	1.00
G:F[3]	0.140	0.134	0.137	0.159	0.151	0.148	0.009	<0.01	0.05	0.94	0.74	0.40
Carcass-adjusted G:F[4]	0.138	0.141	0.151	0.156	0.155	0.166	0.008	<0.01	0.86	0.02	0.60	0.88
HCW, kg	320	322	321	327	323	323	17.85	0.08	0.64	0.82	0.20	0.94
Dressing %	63.28	64.25	65.00	63.26	63.91	65.30	0.35	0.95	0.03	0.01	0.66	0.37
USDA quality grade												
Prime, %	1.04	0.00	1.00	0.00	1.04	2.23	0.90	0.59	1.00	0.24	0.26	0.92
Choice, %	56.89	62.86	61.11	66.94	67.98	61.64	4.72	0.11	0.37	0.30	0.52	0.55
Select, %	39.99	37.14	34.77	32.02	30.98	34.00	5.05	0.13	0.61	0.93	0.81	0.49
Standard, %	2.09	0.00	0.00	1.04	0.00	0.00	0.65	0.52	0.03	1.00	0.43	1.00
Dark cutter, %	1.04	0.00	2.08	0.00	0.00	2.13	1.08	0.72	0.64	0.07	0.64	0.98
Calculated yield grade	2.90	2.83	2.89	2.94	2.86	2.88	0.09	0.71	0.31	0.56	0.91	0.83
USDA yield grade[5]	2.59	2.65	2.66	2.54	2.42	2.54	0.08	0.02	0.64	0.30	0.16	0.34
Yield grade 1,[5] %	6.53	4.17	7.43	8.47	11.82	5.64	2.47	0.21	0.84	0.56	0.26	0.07
Yield grade 2,[5] %	36.68	39.49	35.60	39.27	39.31	42.81	5.17	0.42	0.77	0.97	0.77	0.45
Yield grade 3,[5] %	48.23	45.70	41.89	43.70	41.44	42.78	5.17	0.46	0.58	0.78	0.98	0.55
Yield grade 4 and 5,[5] %	8.56	9.60	14.00	8.56	6.39	8.77	3.33	0.32	0.87	0.32	0.64	0.77
Marbling score[6]	519	517	522	528	531	530	12.98	0.11	0.92	0.80	0.74	0.65
KPH, %	2.34	2.37	2.33	2.36	2.35	2.40	0.06	0.57	0.84	0.98	0.58	0.33
12th rib fat, cm	1.37	1.38	1.46	1.46	1.44	1.39	0.07	0.58	0.84	0.73	0.73	0.21
LM area, cm^2	82.7	84.8	84.7	84.9	85.3	84.0	0.52	0.44	0.24	0.52	0.45	0.53
Liver abscess, %	2.17	2.17	1.00	2.13	2.08	4.64	1.73	0.44	0.99	0.73	0.99	0.32

[1]Contrast 1: Mean of dry-rolled corn diets vs. mean of steam-flaked corn diets. Contrast 2: Mean of diets with 0% dried distillers grains and 15% silage vs. mean of diets containing 25% dried distillers grains and 15% silage. Contrast 3: Mean of dried distillers grains diets with 15% silage vs. mean of dried distillers grains diets with 5% silage. Contrast 4: Grain processing by dried distillers grains interaction with 15% silage. Contrast 5: Grain processing by roughage level interaction with diets containing dried distillers grains.

[2]Dried corn distillers grains with solubles.

[3]Final BW, ADG, and G:F were calculated using final shrunk BW (4% shrink).

[4]Final BW, ADG and efficiency were computed by using carcass-adjusted final BW. Final BW = HCW divided by a common dressing percentage of 63.5 (base grid value).

[5]Yield grade as determined by a USDA grader.

[6]Marbling score 500 = Small.

Widespread availability of distillers grains suggests that they will continue to be an important constituent in feedlot diets. Results of these experiments indicate that distillers grains can be a substitute for DRC or SFC and soybean meal with no deleterious effects on performance or carcass merit. Moreover, including distillers grains in finishing diets may make it feasible to decrease the amount of CS needed in finishing diets without adversely affecting animal performance. Further research is warranted in this area to describe the site and extent of fiber digestion in ruminant animals consuming typical feedlot diets with and without distillers grains.

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