Recent Research with Distiller's Grains and Corn Milling Byproducts – Southern Plains [2, 3]

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Introduction

The bioethanol industry (a dry corn milling process) has grown rapidly over the past 10 years. A major byproduct of ethanol production is distiller's grains. To date, most of the new ethanol plants have been constructed in the Corn Belt and Midwest; however, new mills are planned and being constructed in the southern Great plains. Many of these new plants may use grain sorghum as the starch source. Much of the research on the feeding of distiller's grains and other corn milling byproducts has been conducted in the northern Great Plains. Feedlot diets in the northern plains tend to differ from those fed in the southern plains: corn is generally dry rolled rather than steam flaked; and the roughage source tends to be silage rather than alfalfa or cotton byproducts. Feedyards in the southern plains also tend to be larger than those in the northern plains; thus, management of byproducts, especially wet byproducts, may differ. Environmental issues also tend to differ between the northern and southern Great Plains. Much of the northern plains and corn belt are grain exporting regions; whereas, the southern plains is a grain importing area. Because of this, the high P concentrations in many byproducts are less of a concern in the northern Great Plains than in the southern Great Plains.

Corn gluten feed (CGF) is a wet corn milling byproduct. Over the last several years many feedyards in the southern plains have been using Sweet Bran®, a CGF manufactured by Cargill Inc. as an energy and protein source, replacing a portion of the steam-flaked corn and supplemental protein in growing and finishing diets.

Replacement of highly digestible steam-flaked corn with these corn milling byproduct ingredients could affect animal performance. In addition, the high ruminal undegradable protein, P and S concentrations of these byproducts could have environmental consequences.

Thanks to the National Grain Sorghum Producers (now National Sorghum Producers) in Lubbock, TX, in 2002 the Consortium for Cattle Feeding and Environmental Science received funding to conduct cooperative research studies on the feeding of distiller's grains; especially those based on

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sorghum grain. This review will summarize results from 4 studies partially funded by this project (three cattle feeding studies conducted with sorghum-based and corn-based distiller's grains, one dairy calf feeding study with sorghum-based distiller's grains), as well as one additional cattle feeding study with corn gluten feed partially funded by Cargill. In all trials, the basal diet was based on steam-flaked corn.

Materials and Methods

In 2002 we conducted a short survey of several nutritionists that consult for southern Great Plains feedyards to obtain their opinion on research needs involved with the feeding of distiller's grains. Objectives of these initial studies were to answer questions posed by that survey.

Study 1: Concentration of distiller's grains in finishing diets: Animal Performance (M. L. Galyean and K. A. Lemon).

This study was conducted to determine the optimal dietary concentration of wet distiller's grains in steam-flaked corn-based finishing diets and to compare the feeding value of sorghum-based (WSDG) vs. corn-based (WCDG) wet distiller's grains.

In October 2003, 200 feeder steers (average initial shrunk BW = 713 lb) were shipped from Oklahoma to the Texas Tech University Burnett Center in New Deal, TX. On arrival, each animal was weighed, ear tagged, vaccinated, treated for internal and external parasites and fed a 65% concentrate diet. Approximately 4 d before the start of the trial, cattle were individually weighed and blocked by BW. Steers were randomized to concrete, partially slotted-floor pens at the Burnett Center in early December 2003. All steers were initially implanted with Revalor S (Intervet).

The five experimental diets (Table 1-1) included the following: 1) CON = standard 92.5% concentrate finishing diet; 2) 5% = 92.5% concentrate finishing diet with 5% (DM basis) WSDG; 3) 10% = 92.5% concentrate finishing diet with 10% (DM basis) WSDG; 4) 15% = 92.5% concentrate finishing diet with 15% (DM basis) WSDG; and 5) C10% = 92.5% concentrate finishing diet with 10% (DM basis) WCDG. Distiller's grain replaced a combination of corn, cottonseed meal and urea in the diets. The diets were formulated to contain 13.5% CP, and contained Rumensin and Tylan. To eliminate the potential for excess dietary sulfate, a separate premix that did not contain ammonium sulfate, was used for the diets containing distiller's grains. In this premix, ground corn replaced the ammonium sulfate used in the control premix. Distiller's grains in this study were obtained from plants in New Mexico (WSDG) and Nebraska (WCDG), and stored in silo bags at the Burnett Center.

Feed bunks from each pen in the trial were appraised visually each morning and the quantity of feed delivered was designed to allow for little or no accumulation of feed in the bunk. Cattle were weighed every 28 d on a pen basis using a pen-platform scale. Individual initial- and final-BW were obtained using an individual animal scale.

Based on performance and visual appraisal, blocks of cattle were slaughtered at the Excel Corp. facility in Plainview, TX when 50 to 60% of group was expected to grade USDA Choice. Days on feed ranged from 97 to 141 days with a mean of 133 days. On the morning of shipment, cattle were individually weighed, and fecal grab samples were taken by USDA-ARS personnel (Bushland, TX) for measurement of *E. coli* O157 shedding and diet digestibility (data not reported herein). Carcass data were obtained by personnel of the West Texas A&M University Beef Carcass Research Center.

Data were analyzed as a randomized complete block design using the MIXED procedure of SAS (SAS Inst. Inc., Cary NC). The pen was the experimental unit for all analyses. Specific contrasts were used to test the following treatment responses: 1) the response surface to the graded levels of

WSDG (linear and quadratic); and 2) the comparison of the diet with 10% WSDG and the diet with 10% WCDG.

Table 1-1. Ingredient and chemical composition of diets in Studies 1 and 3 (DM basis)

Ingredient	Treatment diet				
	Control	5% Sorghum DG	10% Sorghum DG	15% Sorghum DG	10% Corn DG
Steam-flaked corn	75.40	73.90	70.68	65.72	71.03
Wet sorghum DG	--	5.37	10.7	15.97	--
Wet corn DG	--	--	--	--	10.20
Cottonseed hulls	7.62	7.59	7.56	7.53	7.60
Molasses	4.25	4.23	4.22	4.19	4.24
Tallow	3.06	3.05	3.04	3.02	3.06
Urea	1.01	1.01	0.77	0.25	0.81
Cottonseed meal	5.86	1.97	--	--	--
Limestone	0.26	0.35	0.52	0.81	0.53
Supplement	2.54	2.53	2.52	2.50	2.52
Chemical component					
DM, %	81.19	76.27	72.57	70.54	71.09
CP, %	11.71	11.82	12.26	12.29	12.17
ADF, %	9.06	9.08	12.07	12.99	10.51
P, %	0.32	0.34	0.38	0.44	0.38

[a] CON = control diet with no added distiller's grains; 5% = 5% added wet sorghum distiller's grains; 10% = 10% added wet sorghum distiller's grains; 15% = 15% added wet sorghum distiller's grains; C10% = 10% wet corn distiller's grains.

Study 2: Wet vs. dry distiller's grains in finishing diets (J. Drouillard, B. E. Depenbusch, E. R. Loe, A. S. Webb, M. E. Corrigan, and M. J. Quinn)

The objectives of this study were to compare the feeding value of wet vs. dry distiller's grains in steam-flaked corn based diets and to evaluate the roughage value of distiller's grains.

Two hundred ninety-nine crossbred-yearling steers (800 lb), obtained from a common source, were used in a completely randomized experiment to evaluate finishing performance of steers fed a control diet or one of six experimental diets containing 15% (DM basis) wet or dried distiller's grains with solubles (DGS). Finishing diets were as follows (Table 2-1): 1) control diet containing no DGS; 2) dried sorghum DGS (DSDG) with 6% alfalfa hay; 3) DSDG without alfalfa hay; 4) WSDG with 6% alfalfa hay; 5) WSDG without alfalfa hay; 6) dried corn

DGS (DCDG) with 6% alfalfa hay; and 7) WCDG with 6% alfalfa hay. On arrival at the KSU feedlot, steers were ear tagged and vaccinated. One week later, animals were revaccinated, treated for parasites, and implanted with Revalor IS.

Individual BW were obtained and used to assign cattle to treatments. Steers were reimplanted with Revalor IS on day 56. Steers were allowed ad libitum access to four step-up diets leading to the final finishing diet (Table 2-1). Steers were housed in 49 concrete-surfaced pens (392 ft^2: 7 pens per treatment; 6 to 7 steers per pen) with overhead shade covering the bunk and half of the pen. Individual pens of steers were weighed on day 27, 56, 83, 101, and just before slaughter using a pen scale. Steers were slaughtered on two separate dates (days 101 and 129) at a commercial facility in Emporia, KS, and carcass data were collected. Final BW was calculated by dividing hot carcass weight by a common dressing percent of 63.5%.

Dry matter and organic matter digestibilities were determined for 21 pens (3 pens/treatment) over a 72-h period during the finishing phase. Before the daily feeding on day 115, any feed that had not been consumed by the steers was removed from the bunks and concrete pen surfaces were thoroughly cleaned. At 24 hour intervals over 3 days, feces were collected from each pen, weighed, and a representative sample (~2%) was obtained from each pen. After 3 days, daily samples for each pen were composited, frozen, and analyzed.

Data were analyzed statistically using the MIXED procedure of SAS with pen as the experimental unit. Pre-planned orthogonal contrasts included: 1) control vs. DGS treatments that included 6% hay; 2) sorghum DGS vs. sorghum DGS without hay; 3) Wet DGS vs. Dry DGS; and 4) sorghum DGS vs. corn DGS.

Table 2-1. Ingredient and calculated chemical composition of diets fed in Study 2

Item	Control	Dry sorghum DGS		Wet sorghum DGS		Corn DGS	
		0 % hay	6% hay	0% hay	6% hay	Dry	Wet
Steam flaked corn	81.1	75.7	70.0	75.3	69.8	69.8	69.8
DGs	0	15.0	15.0	15.0	15.0	15.0	15.0
Alfalfa hay	6.0	0	6.0	0	6.0	6.0	6.0
Limestone	1.9	3.5	3.2	3.2	3.0	3.0	3.0
Soybean meal	4.2	0	0	0	0	0	0
Urea	1.4	0	0	0.8	0.6	0.5	0.5
Nutrient							
CP, %	14.0	14.4	14.0	14.0	14.0	14.0	14.0
Fat, %	3.8	4.6	4.5	4.9	4.8	4.8	4.7
Ca, %	0.7	0.7	0.7	0.7	0.7	0.7	0.7
P, %	0.3	0.3	0.3	0.4	0.4	0.3	0.4

Study 3: Concentration of distiller's grains in finishing diets: Nutrient retention and potential ammonia emissions (L. W. Greene, F.T. McCollum. K. McCuistion; N. A. Cole)

The objectives of this study were to determine the digestibility and feeding value of sorghum- and corn-based distiller's grains in steam-flaked corn finishing diets and to estimate the effects on potential ammonia losses.

Ten crossbred steers were used in a nutrient balance trial. Steers were assigned to one of the five dietary treatments used in Study 1 (Table 1-1) in a replicated 5 x 5 Latin square design. During fecal and urine collections, steers were confined to tie stalls at the USDA-TAES research feedlot at Bushland, TX. Periods of the Latin square were three weeks in length: 10-day diet adaptation, 4-day tie stall adaptation, and 7-day fecal and urine collection. Unacidified feces and urine were collected at 2-hour intervals and immediately frozen. Unacidified feces and urine (1% of average daily excretion) from the steers were used in a lab-scale system (Cole et al., 2004) to estimate potential ammonia emissions.

Study 4: Evaluation of sorghum based distiller's grains for dairy heifer calves (C. R. Richardson and J. Mikus)

The objectives of this study were to determine in vitro digestibility of sorghum distiller's grains and to evaluate dried distiller's grain as a feedstuff in hut rations for dairy heifer calves.

In vitro digestibility measurements were conducted in two evaluations of a WSDG product from New Mexico compared to a corn starch control treatment. In the first evaluation, digestibilities were determined on 90% concentrate diets in which wet distiller's grain was added at levels of 0, 5, 10, and 15% of DM. Incubation times were 12, 24, and 48 hours. In the second evaluation, more extensive replications of the 24 hour incubation time were conducted to obtain a reliable comparison of digestibility across levels of 0, 5, 10, and 15%.

For the feeding study, DSDG were obtained from a plant in Kansas and fed to dairy heifers at a commercial dairy in New Mexico. The DSDG were fed at levels of 0, 5,10, and 15% in their diet (Table 4-1). A total of 192 calves, 48 per treatment, were used in a 56 day study to determine feed consumption and weight gain.

Table 4-1. Composition of experimental diets containing sorghum distiller's grains (DSDGs) fed to dairy heifer hut-calves in Study 4 (% DM basis)

Item	0% DSDGs	5% DSDGs	10% DSDGs	15% DSDGs
Steam flaked corn	40.0	40.0	40.0	40.0
Steam-flaked sorghum	30.0	30.0	30.0	30.0
DSDG supplement	0.0	10.0	20.0	30.0
Non-DSDG Supplement	30.0	20.0	10.0	0.0
Chemical component				
CP, %	19.92	19.01	18.35	19.23
P, %	1.78	1.36	1.48	1.33

Study 5: Corn gluten feed in finishing diets: Animal performance and potential ammonia losses (P. J. Defoor, D.A. Walker, K. J. Malcolm-Callis, and J. F. Gleghorn).

This study was conducted to determine the effects of corn gluten feed and dietary fat concentration on performance of finishing steers.

The 360 steers (Angus and Angus x Charolais) used in the study were purchased in November, 2002 from sale barns in Kansas and were backgrounded for approximately 50 d at a commercial feedyard in Oklahoma. On arrival at the Clayton Livestock Research Center, steers were given booster vaccinations, ear tagged, weighed individually, and sorted to one of six weight blocks and one of five treatment diets (Table 5-1).

A randomized complete block design was used to evaluate experimental diets containing the following CGF/Fat combinations: 1) 0% CGF/3% added fat (STD); 2) 25%

CGF/0% added fat (CGF0); 3) 25% CGF/2% added fat (CGF2); 4) 25% CGF/3% added fat (CGF3); 5) 25% CGF/4% added fat (CGF4).

Table 5-1. Ingredient and chemical composition of the experimental diets fed in Study 5 (DM basis)

Item	STD	CGF0	CGF2	CGF3	CGF4
Steam-flaked corn	77.8	63.3	60.8	59.6	58.3
Corn gluten feed	--	25.0	25.0	25.0	25.0
Alfalfa hay	9.0	9.0	9.0	9.0	9.0
Molasses	4.0	--	--	--	--
Yellow grease	3.0	0.0	2.0	3.0	4.0
Cottonseed meal	2.8	0.0	0.5	0.75	1.0
Urea	0.9	0.2	0.2	0.2	0.2
Supplement	2.5	2.5	2.5	2.5	2.5
Chemical component					
DM, %	78.28	73.12	73.62	73.52	73.48
CP, %	14.53	13.99	13.82	14.04	13.85
ADF, %	5.99	7.60	7.53	8.17	9.90
Ash, %	5.38	5.40	5.54	5.73	5.65
Ca, %	0.89	0.77	0.72	0.83	0.86
P, %	0.34	0.48	0.44	0.44	0.46

Following an 8-day fill-equilibration period, steers were weighed individually, implanted, and started on their assigned diets (d 0; 1/15/03). The heaviest three blocks were implanted with Revalor S (Intervet, Inc.), whereas, the lightest 3 blocks were implanted initially with Component ES with Tylan (Vet Life Inc.) and reimplanted on d 49 with Revalor S. Steers were fed one of five 71% concentrate step-up diets that corresponded to their treatment assignment for 7 d, were switched to one of five 81% concentrate step-up diets corresponding to their treatment assignment for 7 d, and were switched to their final 91% concentrate diets (Table 5-1) for finishing. Quantities of feed delivered each day were targeted so that approximately 0.5 lb of feed per steer remained in the bunk at 0730 before feeding at approximately 0800.

Steers were weighed individually before the morning feeding on day 0, 49, and the day of slaughter (average 121 days on experimental diets). When the majority of steers within a block had approximately 0.5 inches of backfat, they were slaughtered at a commercial packing plant near Amarillo, TX and carcass data were collected by personnel of the West Texas A&M University Beef Carcass Research Center. Steers were slaughtered on one of four dates: 4/24; 5/6; 5/20; and 6/4/03. At slaughter, the manure on the feed bunk slab was scraped, mixed and sampled. Samples of manure and rations were analyzed for N and P to estimate N volatilization losses using the difference in the N:P ratio of diets and manure (Todd et al., 2005).

Animal performance and carcass data were analyzed as a randomized complete block design with pen as the experimental unit using the GLM procedure of SAS. The following non-orthogonal contrasts were used to test treatment effects when the overall F-value for treatment was significant ($P < 0.10$): 1) STD vs the average of CGF2, CGF3, and CGF4

{CGF2,3,4}; 2) STD vs CGF3; 3) STD vs CGF4; and 4) CGF0 vs CGF2,3,4. Carcass quality grade data were evaluated using Chi-square analysis with the GENMOD procedure of SAS.

Results and Discussion

Study 1: Concentration of distiller's grains in finishing diets: Animal Performance (M. L. Galyean and Kurt Lemon)

Chemical composition of the diets is presented in Table 1- 1. The CP values of the diets were lower than the formulated value of 13.5% CP, ranging from 11.71 to 12.29%. As expected, ADF values of the diets increased as the percentage of distiller's grain increased (NRC, 1996).

The NEm and NEg concentrations of each diet were calculated by two methods. The first method used the NRC (1996) tabular NE values for each ingredient in the diet. The second method used animal performance data to estimate the NE content of the diets using a quadratic equation derived from the NRC equations (Zinn and Shen, 1998). Values obtained by the two methods are presented in Table 1- 2. The NEm and NEg values calculated based on animal performance for the control and the WCDG diets were greater than tabular values, whereas, values for the 5, 10, and 15% WSDG diets were similar for tabular- and performance-based calculation methods. These differences between the two types of distiller's grains could relate to particle size (i.e., the WCDG was visually finer in texture than the WSDG), to normal variation in the chemical composition of the distiller's grains, and/or to the availability of a greater data base on which to estimate tabular NE values of corn-based than sorghum-based distiller's grains.

There was a linear decrease ($P = 0.03$) in calculated NEm and NEg values as the concentration of sorghum distiller's grain increased in the diet. These results tend to contrast with previous experiments (Ham et al. 1994; Lodge et al. 1997; Trenkle 1997a) in which dry rolled corn, rather than steam-flaked corn comprised the dietary grain source. Thus, the feeding value of distiller's grains might differ, depending on the energy value of the grain source in the finishing diet. The calculated NE values of the sorghum-based (10%) and corn-based distiller's grain diets were not different ($P = 0.16$).

Table 1-2. Dietary net energy calculations (Mcal/cwt) based on tabular values or based on performance data for cattle fed varying levels of wet sorghum distiller's grain and one level of wet corn distiller's grain in Study 1

Treatment	Formulated[a]		Calculated[bcd]	
	NEm	NEg	NEm	NEg
Control	97.7	66.8	100.4	69.1
5% sorghum DG	98.2	67.3	98.2	67.7
10% sorghum DG	98.6	67.7	98.6	67.7
15% sorghum DG	98.6	67.7	95.9	65.4
10% corn DG	98.6	67.3	100.9	70.0

[a] Determined from tabular values (NRC, 1996).

[b] Determined by the quadratic equation of Zinn and Shen (1998).

[c] The linear effect of wet sorghum distiller's grains was significant ($P = 0.03$) for both NEm and NEg. No other contrasts were significant ($P \geq 0.16$).

[d] Pooled SEM for NE_m was 0.02 and for NE_g was 0.01; n = 8 pens per treatment.

Table 1-3. Dry matter intake, and carcass-adjusted average daily gain and feed efficiency by cattle fed varying levels of wet sorghum distiller's grain and one level of wet corn distiller's; grains in Study 1.

Item	Distiller's grain treatment					SEM	*P*-value[b]
	Control	5% S	10% S	15% S	10% C		
DMI, lb/d							
0 to 28	18.6	18.8	17.7	17.1	16.8	0.95	L**
0 to 56	18.4	18.9	17.9	16.7	17.0	1.03	L**
0 to 84	18.5	19.1	18.0	17.2	17.1	1.03	L**
Finish	18.6	19.3	18.5	18.0	17.5	0.95	NS
ADG, lb/d							
0 to 28	4.03	4.11	3.78	3.54	3.76	0.40	L*
0 to 56	3.70	3.78	3.50	2.90	3.28	0.33	L**
0 to 84	3.65	3.76	3.41	3.08	3.32	0.26	L**
Finish[c]	3.32	3.41	3.12	2.84	3.08	0.26	L**
Feed:Gain							
0 to 28	4.62	4.57	4.67	4.83	4.47	0.17	NS
0 to 56	4.98	4.99	5.11	5.76	5.18	0.18	L**
0 to 84	5.07	5.07	5.27	5.60	5.15	0.15	L**
Finish[c]	5.62	5.66	5.92	6.36	5.69	0.18	L**

[a] CON = control diet; 5% = 5% added wet sorghum distiller's grains; 10% = 10% added wet sorghum distiller's grains; 15% = 15% added wet sorghum distiller's grains; and C10% = 10 % added wet corn distiller's grains.

[b] Contrast probability value: Lin = linear contrast among wet sorghum distiller's grains levels; * = $P < 0.05$; ** = $P < 0.01$.

[c] Adjusted final BW was calculated from hot carcass weight assuming an average dressing percent of 61.3%.

Animal performance data are presented in Table 1-3. There was a linear decrease ($P \leq 0.01$) in DMI as the percentage of sorghum distiller's grains increased for d 0 to 28, d 0 to 56, and d 0 to 84. For the overall study, the effect of sorghum distiller's grain concentration on DMI was not significant ($P > 0.14$); however, the numerical trend was the same as in the earlier portions of the feeding period, with lower DMI as the level of sorghum distiller's grain increased in the diet. These results tend to agree with results of previous studies that also noted a decrease in DMI with increasing dietary moisture and/or distiller's grains concentration (Ham et al., 1994; Larson et al., 1993; Trenkle, 1997a) but contrast with the results of Lodge et al. (1997) who reported no differences in DMI between sorghum distiller's grain in the wet or dry form, although the DMI for the treatment that included the wet form was numerically less than the control and dry forms. There was a 10% decrease in the DM content of the diets (Table 1.1), which could have possibly been related to the decrease in intake.

The DMI of the steers fed the 10% WCDG diet was less than the steers fed the 10% WSDG treatment. In contrast, using dried products, Ward and Matsushima (1981) observed no differences in DMI, ADG, or efficiency when they compared corn- and sorghum-based distiller's grain.

There was a linear decrease ($P = 0.01$) in the final carcass-adjusted BW as the dietary concentration of sorghum distiller's grains increased (1,333, 1,335, 1,309, 1,274, and 1,287 lb for the Control, 5%, 10%, 15%, and C10% treatments, respectively); however the 10% WSDG and 10% WCDG treatments did not differ ($P = 0.26$).

As the dietary concentration of WSDG increased there was a linear decrease ($P \leq 0.01$) in ADG for all feeding periods with a tendency for a quadratic effect ($P = 0.08$). Differences in dietary moisture and ADF content may be responsible for the negative relationship between distiller's grain concentration and ADG. In contrast, with dry rolled corn based diets, Larson et al. (1993) and Ham et al (1994) reported a linear increase in ADG with increasing amounts of wet distiller's grains. Trenkle (1997a), however, noted no differences in ADG when wet distiller's grains replaced cracked corn at 40% of the diet (DM basis).

Unlike previous studies (Larson et al., 1993; Ham et al., 1994; Lodge et al., 1997), which reported improved feed efficiency in cattle feed distiller's grain, there was a linear increase ($P < 0.001$) in F:G (i.e. poorer feed conversion) with increasing WSDG concentration during feeding periods d 0 to 56 and d 0 to 84 and for carcass-adjusted feed conversion over the entire trial. There was a tendency for a quadratic increase ($P < 0.10$) for periods d 0 to 56 and d 0 to finish. There was no difference in feed conversion of steers fed WCDG and WSDG ($P = 0.58$); however, cattle fed the 10% WCDG diet were numerically more efficient than those fed the 10% WSDG.

These results differ somewhat from the results of Daubert et al (2005), who fed steam-flaked corn based diets containing 0, 8, 16, 24, 32, or 40% (DM basis) WSDG. Peak performance occurred with 8 to 16 % distiller's grain and performance decreased significantly with higher distiller's grain concentrations. However the formulated CP concentrations and the urea concentrations of the diets fed by Daubert et al (2005) were higher than in the present study.

The lack of response to distiller's grain noted in the present study could be due to a degradable intake protein (DIP) deficiency. The experimental diets were formulated to be isonitrogenous; therefore, as the dietary concentration of distiller's' grain increased the concentration of urea in the diet was decreased. Based on tabular values (NRC, 1996), formulated DIP, as a percentage of dietary DM, were 7.05, 6.72, 6.33, 5.39, and 6.49 % for the control, 5% sorghum-, 10% sorghum-, 15% sorghum- and 10% corn-based distiller's grain diets, respectively. Cooper et al (2002) reported that steam flaking increased the dietary DIP requirement (compared with dry rolling) because of increased ruminal starch digestion and suggested that DIP values between 7.1 and 9.5% of dietary DM (59.7 to 66.4% of dietary CP) were needed in steam-flaked corn-based diets to maximize performance. Thus, based on the estimates of Cooper et al. (2002), the DIP concentrations of the diets in this study were deficient for all diets except the control diet. The DIP values match closely with the observed performance data. Based on these results, an additional trial is currently in progress to evaluate the effects of dietary DIP concentration on performance of steers fed steam-flaked corn-based diets containing distiller's grains.

The hot carcass weight and longissimus muscle area decreased linearly ($P = 0.009$) as WSDG increased in the diet (data not shown). These results likely reflect differences in ADG and final BW because dressing percent did not differ ($P > 0.28$) among treatments. Yield grade tended to increase linearly ($P = 0.09$) as WSDG increased in the diet, reflecting the smaller longissimus muscle area. Steers fed the 10% WCDG diet had lower ($P = 0.02$) yield grade than steers fed the 10% sorghum treatment. Although none of the fat indices were significant ($P > 0.24$), they were all generally numerically higher for the sorghum-based distillers grain treatments than the corn-based distiller's grain treatment, despite the fact that ADG and hot carcass weight were significantly higher for the control diet. Marbling score or the number of cattle that graded Choice or greater did not differ among treatments ($P \geq 0.27$). Effects of distiller's grain on carcass measurements have varied (Lodge et al., 1997; Ham et al., 1994; Larson et al., 1993; Trenkle (1997a).

Study 2: Wet vs. dry distiller's grains in finishing diets (Drouillard, Depenbusch, Loe, Webb, Corrigan, and Quinn)

Steer performance data is presented in Table 2-2. Dry matter intake, carcass-adjusted ADG and final BW were lower ($P < 0.01$) for steers fed diets containing DSDG without hay than for steers fed DSDG with hay. However, carcass adjusted feed conversions were not affected by treatment. Dry matter and organic matter digestibilities were similar for DSDG diets with and without hay.

Similarly, removal of ground alfalfa hay from WSDG-based diets decreased DMI: however, ADG, feed efficiencies and final BW of steers fed diets containing WSDG diets with and without hay were not significantly different. Dry matter digestibility and organic matter digestibility were lower for WSDG diets with hay than for WSDG diets without hay.

Dry matter intake was not significantly different between steers fed DSDG or WSDG diets. When no alfalfa hay was added to the diet, steers fed the WSDG gained more rapidly ($P = 0.04$), were more efficient ($P < 0.01$), and had higher organic matter digestibilites ($P < 0.05$) than steers fed DSDG. Similarly, carcass adjusted final BW ($P = 0.14$) and DM digestibility ($P = 0.08$) tended to be higher for WSDG when no alfalfa hay was in the diet.

When diets contained 6% alfalfa hay, DMI, ADG, feed efficiency, carcass adjusted final BW, DM digestibility, and organic matter digestibility were similar ($P > 0.19$) between DSDG and WSDG diets. Dry matter intake, ADG, feed efficiency, DM digestibility and organic matter digestibility were similar for steers fed sorghum-based and corn-based distiller's grains ($P > 0.22$).

Removing alfalfa hay from the diet of steers fed sorghum-based distiller's grains resulted in lower carcass weights and lower USDA yield grades ($P < 0.05$: data not shown). Marbling score, percent USDA Choice or better carcasses, longissimus area, and liver abscesses did not differ among treatments ($P > 0.21$). Steers fed sorghum-based distiller's grain with hay had greater fat thickness over the 12th rib and a lower dressing percent than animals fed no hay ($P < 0.05$). Carcass weights, yield grade, percent USDA Choice or better carcasses, marbling score, longissimus area, 12th rib fat thickness, and liver abscess were not different ($P > 0.21$) between wet and dry sorghum-based distiller's grain. However, steers fed WSDG diets had a higher dressing percentage than steers fed DSDG diets ($P < 0.05$).

Carcass weight, yield grade, marbling score, percent USDA Choice or better carcasses, longissimus area, and 12th rib fat thickness were not different between steers fed corn- and sorghum-based distiller's grains ($P > 0.31$). Steers fed corn-based distiller's grain had a higher dressing percentage than steers fed sorghum-based distiller grain ($P < 0.01$).

This study indicates that distiller's grains with solubles derived from sorghum and corn have comparable nutritional value for feedlot cattle when added to steam-flaked corn- based finishing diets at 15% of the dietary DM. Likewise, wet and dry distiller's grains had similar feeding values. Removal of alfalfa hay from wet and dry sorghum-based distiller's grain diets adversely affected DMI, ADG, and final BW.

Study 3: Concentration of distiller's grains in finishing diets: Nutrient retention and potential ammonia emissions (L. W. Greene, F.T. McCollum. K McCuistion; N. A. Cole)

Feeding distiller's grain tended to decrease nitrogen digestion and urinary N excretion as a percentage of N intake (Table 3-1). This was probably a result of replacement of readily degradable N (ie. urea) with less degradable protein in the distiller's grain. Nitrogen retention was similar for all diets. Although dietary P concentration increased with increasing dietary distiller's grain content (Table 1-1), because of differences in DMI, dietary P intake and P metabolism were not affected by distiller's grain concentration or source.

Potential ammonia emissions, estimated in our lab-scale system were not affected by diet (data not shown)

Table 3-1. Nitrogen and phosphorus metabolism of steers fed steam-flaked corn based diets containing wet distiller's grains in Study 3 (tentative data)

Item	Diet				
	Control	5% Sorghum DG	10% Sorghum DG	15% Sorghum DG	10% Corn DG
DMI, kg	6.60	6.13	6.51	6.38	6.03
N intake, g	168.0 [a]	155.8 [a]	169.6 [a]	169.4 [a]	140.5 [b]
Urine N, g/d	81.2[a]	74.2[a]	78.4[a]	76.8[a]	65.4[b]
Fecal N, g/d	32.6	34.5	41.0	39.0	30.8
Urine N, % intake	71.7[a]	67.8[b]	65.4[b]	66.6[b]	67.9[b]
Retained N, g/d	54.2	47.1	50.2	53.6	44.2
Retained N, % of intake	30.8	30.2	29.4	30.9	31.5
N digest., %	80.5	78.1	75.7	76.7	78.1
P intake, g/d	23.3	21.5	24.4	24.4	22.1
Urine P, g/d	4.17	5.18	4.70	5.25	4.30
Fecal P, g/d	7.90	7.05	8.70	7.22	7.50
Urine P, % of intake	34.5	39.1	33.8	39.6	35.1
P retained, g/d	11.2	9.22	10.9	12.0	10.3
P retained, % of intake	47.5	43.2	44.6	48.8	47.0
P digestion, %	65.5	67.1	64.8	69.8	66.1

Study 4: Distiller's grains for dairy calves (Richardson and Mikus)

In vitro dry matter digestibilities (Table 4-2) tended to be lower for diets containing 5 and 10% wet sorghum distiller's grains than for diets containing 0 or 15% wet distiller's grains. This may be due to the concentration of readily soluble components in the distiller's grains that are lost during centrifugation/filtration in the in vitro procedure.

Although not statistically significant, heifer dairy calves not fed distiller's grains tended to have higher ADG and better feed conversion than heifers fed distiller's grains (Table 4-3). In calves fed distiller's grains, however, performance did not seem to be affected by the concentration of distiller's grain in the diet.

Table 4-2. In vitro digestibility of 90% concentrate diets containing sorghum-based distiller's grains in Study 4

Hours	% Wet sorghum-based DG (DM basis)				Contrast
	0%	5%	10%	15%	
Trial 1					
12	55.55	53.76	53.14	58.32	L < 0.02
24	75.03	72.91	72.35	73.61	NS
48	80.46	78.12	79.12	81.88	L < 0.01
Trial 2					
24	62	59	62	69	--

Table 4-3. Performance of dairy heifer hut-calves fed diets containing dried sorghum distiller's grains (DSDGs) in Study 4.

Item	0% DSDGs	5% DSDGs	10% DSDGs	15% DSDGs
ADG, lb				
d 0-28	0.98	0.87	0.91	0.92
d 29-56	1.72	1.55	1.55	1.57
d 0 -56	1.35	1.21	1.23	1.24
DMI,lb				
d 0-28	4.92	5.14	5.13	4.90
d 29-56	9.94	10.09	9.72	10.12
d 0 -56	7.69	7.62	7.42	7.51
Feed:gain				
d 0-28	5.02	5.91	5.64	5.33
d 29-56	5.78	6.51	6.27	6.44
d 0-56	5.69	6.30	6.04	6.06

Study 5: Corn gluten feed in finishing diets: Animal performance and potential ammonia losses (Defoor, Walker, Malcolm-Callis, and Gleghorn)

Performance data based on final live weight and carcass adjusted final weight are presented in Table 5-2. Dry matter intake was greater for the CGF3 ($P = 0.01$), CGF4 ($P = 0.01$), and for the average of the CGF2, CGF3, and CGF4 diets ($P = 0.002$) than for the STD diet. Compared to steers fed the STD diet, steers fed the CGF3 and CGF4 diets had 3.3% ($P =$

0.11) and 7.1% ($P = 0.002$), greater ADG, respectively. The mean ADG of steers fed the CGF2, CGF3, and CGF4 diets, which provided an average of 3% added fat, was approximately 5.7 % greater ($P = 0.002$) than the ADG of steers fed the STD diet with 3% added fat. The addition of fat to the CGF diets increased ADG ($P = 0.002$) and DMI ($P = 0.03$) compared to the CGF0 treatment. The overall F:G was not significantly affected by diet ($P = 0.30$).

Hot carcass weight was the only carcass characteristic that differed statistically among treatments (data not shown). Differences in carcass weight reflected differences in ADG. Numerically ($P > 0.49$), the proportion of steers fed the CGF2, CGF3, and CGF4 diets that graded Choice of higher was greater (43.8% vs 34%) than the proportion of steers fed the STD diet.

The dietary NEm and NEg values of the STD diet, calculated from animal performance, were 108.2% and 110.6%, respectively, of the NEm and NEg values for this diet calculated using tabular NE values for the ingredients (NRC, 1996). Therefore, the NEm and NEg value of each ingredient was multiplied by 1.082 and 1.106, respectively, before calculating the NEm and NEg values for the CGF by iteration. This adjustment increased the NEm and NEg values (NRC, 1996) of the steam-flaked corn from 105.7 and 73.5 Mcal/cwt, respectively, to 114.3 and 81.2 Mcal/cwt, respectively. Based on these revised values, the average NEm and NEg values for the CGF in the CGF2, CGF3 and CGF4 diets were estimated to be 95.3 and 65.3 Mcal/cwt: approximately 80.4% of the NEg value of steam-flaked corn. This is very similar to results of a Texas Tech study reported by Parsons et al. (2001) in which CGF was fed at 40% of dietary DM. The NEg of the steam-flaked corn in that study was reported to be approximately 81.6 Mcal/cwt. In light of the relatively large difference in the NEg concentration of CGF and steam-flaked corn, it is somewhat surprising that feed:gain differed by only 2% . This relationship might illustrate limitations to the use of calculated NEg values of individual feedstuffs when large differences in DMI are observed in finishing trials.

Table 5-3. Commodity prices used for economic analysis in Study 5.

Item	Cost[a]
Steam-flaked corn	$125.00/ton
Sweet Bran®	$118.30/ton
Alfalfa hay	$125.00/ton
Steep/molasses blend	$120.00/ton
Yellow grease	$240.00/ton
Cottonseed meal	$177.00/ton
Urea	$220.00/ton
Finish supplement	$185.00/ton
Yardage	$0.35/day
Steer cost/cwt at initial weight	$85/cwt
Final live price	$78.50/cwt

The prices used for economic calculations are presented in Table 5-3. Costs of gain were lower for the CGF diets (average of CGF2, CGF3 and CGF4) than for the STD diet ($43.49 vs. $44.38/cwt), and the average profit for the steers fed the CGF2, CGF3 and CGF4 diets was $12.53 greater than steers fed the STD diet. The breakeven price for CGF in this case was approximately 128% that of steam-flaked corn (DM basis). Costs of gain were similar for steers fed the CGF3 and STD diets ($44.51/cwt vs. $44.38/cwt); however, because of greater saleable carcass weight, steers fed the CGF3 diet returned $4.12 more profit per animal than steers fed the STD diet. The breakeven price for CGF in this comparison was approximately 105% that of steam-flaked corn (DM basis). Individuals should apply their own ingredient costs and inventory gain/shrink relationships to these performance data.

Based on the calculated NEg concentration determined for CGF one might assume that CGF priced at 95% of steam-flaked corn (DM basis) would result in higher costs of gain for the steers fed the CGF diets. However, these performance and economic data raise the intriguing question of how replacing a higher energy feedstuff (steam-flaked corn) with a lower energy feedstuff such as CGF at a similar price can result in the favorable economic outcome observed. Four explanations for this observation are likely. 1) Although dietary NEg concentration was lower in diets containing CGF, total NEg intake per day was greater: this was beneficial in terms of ADG and profitability. 2) The NEg concentration of CGF could be underestimated. When calculating NEg by difference, any inaccuracies in the calculation of the energy values of ingredients would be accumulated in estimating the NEg concentration of CGF. 3) A portion of the economic advantage of CGF in this study was protein cost savings. Supplemental protein costs (DM basis) were $6.94/ton for the STD diet, but averaged only $1.77/ton for the CGF diets (average of CGF2, CGF3, and CGF4). 4) Some studies suggest that CGF may decrease the severity or incidence of clinical and/or subclinical acidosis by decreasing the dietary starch and increasing the dietary fiber content. By significantly improving the performance of a few animals in a group, overall performance may not be markedly improved, but the overall economic picture could be improved.

Results of this study indicate that the economic value of CGF should not be based solely on its estimated NEg value relative to steam-flaked corn. With this particular set of steers, increases in DMI were favorable and resulted in greater ADG, more saleable carcass weight, and overall greater profitability by steers fed CGF . Protein cost savings in these diets contributed heavily to the economic advantage of CGF. Performance responses to fat additions suggest that the choice of fat level ranging from 2 to 4% of dietary DM in diets containing CGF should likely be dictated by the cost of fat and not by concerns about associative effects between CGF and fat.

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Table 2-2. Performance of yearling steers fed steam-flaked corn based finishing diets containing wet or dry distiller's grains and fed for 114 days in Study 2.

Item	Control	Dried – Sorghum DG		Wet-Sorghum DG		Corn DG		SEM
		0% hay	6% hay	0% hay	6% hay	Wet	Dry	
Initial wt, lb	803	798	802	803	804	792	800	32
Final wt, lb	1,155[b]	1,100[a]	1,150[b]	1,134[ab]	1,142[ab]	1,149[ab]	1,146[ab]	25
DMI, lb/d	20.6[b]	19.1[a]	21.1[b]	19.2[ab]	20.7[b]	20.9[b]	20.3[b]	0.60
ADG, lb/d	3.18[c]	2.70[a]	3.11[bc]	2.98[b]	3.03[b]	3.19[c]	3.11[bc]	0.10
Feed:gain	6.49[a]	7.06[b]	6.77[ab]	6.45[a]	6.80[b]	6.54[a]	6.53[a]	0.16
Apparent digestibility, %								
Dry matter	83.8[c]	83.9[c]	82.6[bc]	86.4[d]	80.1[a]	81.2[ab]	82.0[bc]	0.90
Organic matter	86.8[b]	86.4[b]	85.2[b]	89.0[c]	83.4[a]	84.0[ab]	85.0[ab]	0.85

Table 5-2. Effects of corn gluten feed and added fat level on performance by finishing beef steers in Study 5

Item	Treatment[a]					SEM[b]
	STD	CGF0	CGF2	CGF3	CGF4	
Initial BW, lb	770.0	773.8	772.1	773.9	772.6	2.44
Final BW[b], lb	1,243.5	1,248.0	1,276.1	1,262.6	1,280.0	7.14
ADG, lb	3.93	3.93	4.19	4.06	4.21	0.05
DMI, lb/d	18.28	18.74	19.81	19.63	19.54	0.33
Feed/Gain	4.64	4.77	4.73	4.84	4.64	0.07
% Choice	34.0	26.6	43.1	46.0	42.4	--
Profit/steer[d], $	94.52	98.72	110.38	98.64	112.14	--

[a] STD = Standard steam flaked corn based diet with 3% added fat (DM basis); CGF0 = Steam flaked corn based diet with 25% CGF and 0% added fat, (DM basis); CGF2 = 25% CGF with 2% added fat (DM basis); CGF3 = 25% CGF with 3% added fat (DM basis); CGF4 = 25% CGF with 4% added fat (DM basis).

[b] Pooled standard error of the treatment means, n = 6 pens per treatment.

[c] Weighted average days on feed = 121.

[d] Based on prices presented in Table 5-3

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