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Effects of wet corn gluten feed and roughage levels on performance, carcass characteristics, and feeding behavior of feedlot cattle[1]

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ABSTRACT: Two experiments were conducted to evaluate the effects of feeding different levels of wet corn gluten feed (WCGF) and dietary roughage on performance, carcass characteristics, and feeding behavior of feedlot cattle fed diets based on steam-flaked corn (SFC). In Exp. 1, crossbred steers (n = 200; BW = 314 kg) were fed 4 dietary treatments (DM basis): a standard SFC-based diet containing 9% roughage (CON) and 3 SFC-based diets containing 40% WCGF, with either 9, 4.5, or 0% roughage. A linear (P = 0.04) increase in final BW and DMI (P < 0.01) was observed in diets containing WCGF as dietary roughage increased. Steers fed WCGF and higher levels of roughage had greater (P = 0.01) ADG than steers fed lower levels of roughage. Steers fed the CON diet had lower (P = 0.04) daily DMI and greater (P = 0.03) G:F than those fed WCGF. Most carcass characteristics of steers fed CON did not differ (P > 0.10) from those of steers fed WCGF. Based on feed disappearance and visual scan data, consumption rate did not differ (P > 0.10) among treatments; however, feeding intensity (animals present at the bunk after feeding) was greater for steers fed CON (P < 0.01) than for steers fed WCGF. In Exp. 2, yearling crossbred steers (n = 1,983; BW = 339 kg) were fed 4 dietary treatments (DM basis): a standard SFC-based control diet that contained 9% roughage (CON) and 3 SFC-based diets containing either 20% WCGF and 9% roughage or 40% WCGF with 9 or 4.5% roughage. Steers fed the CON diet tended to have lower final BW (P = 0.14), ADG (P = 0.01), and DMI (P < 0.01) than steers fed diets containing WCGF. Steers fed the 20% WCGF diet had greater (P = 0.08) G:F than steers fed the 40% WCGF diets. With 40% WCGF, increasing roughage from 4.5 to 9% decreased (P < 0.01) G:F and increased (P = 0.06) DMI. Gain efficiency was improved (P < 0.01) for steers fed CON vs. those fed diets containing WCGF, whereas HCW (P = 0.02) and dressing percentage (P < 0.01) were greater for steers fed WCGF. Percentage of cattle grading USDA Choice was greater (P = 0.02) for cattle fed WCGF. Results suggest that replacing SFC with up to 40% WCGF increased ADG and decreased G:F when 4.5 to 9.0% roughage was supplied. More CON steers were present at the feed bunk during the first hour after feeding than WCGF steers, suggesting that including WCGF at 40% of the diet affected feeding behavior.

Key words: beef cattle, feeding behavior, feedlot, roughage level, wet corn gluten feed

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INTRODUCTION

Wet corn gluten feed (**WCGF**) is a coproduct of the wet corn milling industry that is a valuable source of highly digestible fiber and CP in growing and finishing beef cattle diets. Previous research has shown that the NE concentration of WCGF is 93 to 101% or 113 to 115% of dry-rolled corn (**DRC**), depending on the source (Stock et al., 2000). Results reported by Hussein and Berger (1995), Haugen and Hughes (1997), and Richards et al. (1998) suggested that maximal ADG and feed intake occurred when WCGF replaced 50% or less of the DRC in the diet. Less research has been done regarding the feeding value of WCGF relative to steam-flaked corn (**SFC**).

Feeding and nonfeeding behavior patterns of grazing beef cattle have been well documented (Phillips, 1993; Albright and Arave, 1997). Cattle are social animals

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that operate within a herd structure whether they are in a feedlot or on pasture. As a result of limited feeding, watering, and living space, cattle in concentrated feeding operations typically exhibit greater social interaction than grazing cattle. Feed ingredients like WCGF that contain digestible fiber might alter feeding behavior by increasing total time spent at the feed bunk (Putnam and Davis, 1963), but the extent to which dietary alterations affect feeding behavior is not well defined. The inclusion of WCGF in finishing diets also has been reported to decrease incidence and severity of acidosis, likely because of the addition of highly digestible fiber to high-starch diets (Krehbiel et al., 1995). Decreased acidosis when WCGF is fed also might be a result of altered feeding behavior; however, no research has been conducted on this topic.

The objective of our 2 experiments was to investigate the effects of different levels of WCGF (Sweet Bran, Cargill Inc., Blair, NE) and dietary roughage on finishing performance, carcass characteristics, and feeding behavior of feedlot cattle.

Table 1. Composition and analyzed nutrient content (DM basis) of experimental diets in Exp. 1

	Treatment[1]			
Item	CON	W9.0	W4.5	W0.0
Ingredient				
Steam-flaked corn	73.86	45.38	48.97	52.29
WCGF	—	39.78	39.75	39.77
Alfalfa	9.13	9.17	4.54	—
Cottonseed meal	6.12	—	1.17	2.34
Urea	1.11	—	—	—
Fat (yellow grease)	3.01	3.15	3.02	3.03
Molasses	4.25	—	—	—
Control supplement[2,3]	2.52	—	—	—
W9.0 supplement[2,4]	—	2.52	—	—
W4.5 supplement[4]	—	—	2.55	—
W0.0 supplement[2,4]	—	—	—	2.57
Analyzed composition				
DM, %	81.76	70.76	70.18	70.15
CP, %	14.65	14.39	14.67	14.84
Ca, %	0.74	0.50	0.54	0.53
P, %	0.34	0.61	0.64	0.66
Ash, %	4.95	5.63	5.74	5.35
ADF, %	7.37	8.87	7.13	5.01

[1]CON = control; W9.0 = 40% wet corn gluten feed (WCGF) with 9% alfalfa hay; W4.5 = 40% WCGF with 4.5% alfalfa hay; W0.0 = 40% WCGF with no added roughage. Sweet Bran wet corn gluten feed was supplied by Cargill Inc. (Blair, NE).

[2]All supplements contained the following (DM basis): 3.56% magnesium oxide, 12.00% salt, 0.002% cobalt carbonate, 0.13% iron sulfate, 0.003% ethylenediamine dihydroiodide, 0.27% manganese oxide, 0.10% Se premix (0.2% Se), 0.83% zinc sulfate, 0.01% vitamin A (650,000 IU/g; 90% DM basis), 0.13% vitamin E (275 IU/g; 90% DM basis), 0.68% Rumensin 80 (Elanco Animal Health, Indianapolis, IN), and 0.36% Tylan 40 (Elanco Animal Health).

[3]Supplement for CON also included the following: 23.97% cottonseed meal, 42.11% limestone, 1.04% dicalcium phosphate, 8.0% potassium chloride, 6.67% ammonium sulfate, and 0.16% copper sulfate.

[4]Supplement for W9.0 also included the following: 28.27% ground milo, 52.63% limestone, and 1.07 SQM copper (a polysaccharide complex of Cu; Quali Tech Inc., Chaska, MN). Supplement for W4.5 also included the following: 20.34% ground milo, 60.63% limestone, and 1.07 SQM copper. Supplement for W0.0 also included the following: 12.45% ground milo, 68.42% limestone, and 1.07 SQM copper (a polysaccharide complex of Cu; Quali Tech Inc.).

MATERIALS AND METHODS

All procedures in Exp. 1 involving live animals were conducted within the guidelines of and approved by the Texas Tech University Animal Care and Use Committee. Procedures involving animals in Exp. 2 followed guidelines suggested by FASS (1999).

Exp. 1

Two hundred crossbred steers (Brangus and Angus; average initial BW = 314 ± 10.3 kg) were purchased from the Stone Ranch in Uvalde, TX, and were shipped to the Texas Tech University Burnett Center located 9.7 km from New Deal, TX, in late November. All cattle were vaccinated the morning after arrival with Fortress 7 (*Clostridium chauvoei-septicum-novyi-sordellii-perfringens* types C and D bacterin toxoid; Pfizer Animal Health Inc., Lee Summit, MO) and BoviShield 4 (IBR-PI3-BRSV-BVD preparation; Pfizer Animal Health) and treated for internal and external parasites with Dectomax (doramectin; Pfizer Animal Health). Each animal was identified with a uniquely numbered ear tag, after which the cattle were allotted to pens with concrete, partially slotted flooring and fence-line feed bunks and water troughs. All pens were of similar design, construction, and identical dimensions (2.9 m wide × 5.6 m deep; 2.4 m of linear bunk space).

Four treatments were evaluated, including the following (DM basis; Table 1): a standard SFC-based diet containing 9% roughage (CON) and 3 SFC-based diets containing either 40% WCGF and 9% roughage (W9.0), 40% WCGF and 4.5% roughage (W4.5), or 40% WCGF and 0% roughage (W0.0). Chopped alfalfa hay was the roughage source in all diets. The WCGF (Sweet Bran; Cargill Inc., Blair, NE) replaced portions of SFC, molasses, urea, and cottonseed meal in the diet. All finishing diets were formulated to contain approximately 14.4% CP. Each diet contained 1 of 4 supplements at 2.5% of the dietary DM that provided vitamins, trace minerals, and feed additives [monensin (Rumensin) and tylosin (Tylan); Elanco Animal Health, Indianapolis, IN].

Steers were blocked by BW, with treatments assigned randomly within contiguous blocks of 4 adjacent pens. Final allotment consisted of 5 steers/pen, with 10 pens/treatment. At the time of allotment to the pens, steers were implanted with Ralgro (36 mg of zeranol; Schering-Plough Animal Health, Union, NJ). Steers were reimplanted with Revalor-S (120 mg of trenbolone acetate and 24 mg of estradiol; Intervet Inc., Millsboro, DE) on d 56 of the study. Cattle were fed a 64% concentrate starter diet from the time of arrival until 15 d later when the experiment began. On d 0 of the experiment, cattle were switched to a 73% concentrate diet and subsequently adapted to the final diets by increasing the total concentrate level to 82 and 91% at 5- to 7-d intervals. Additional steps were made in 5- to 7-d intervals for the 2 treatments that received less than 9% dietary roughage, such that cattle in the W0.0 treatment group received their finishing diet by d 26 of the study. Intake on the day of a dietary change was limited to a quantity of feed that provided a calculated intake of NE_g equal to that on the previous day.

Cattle were fed once daily in quantities sufficient to ensure ad libitum consumption. Feed bunks were evaluated visually each day of the experiment at approximately 0700 to determine the quantity of feed to offer each pen. The bunk management strategy was designed to allow for 0 to 0.2 kg of feed remaining at the time of evaluation. After determining the quantity of feed to offer each pen, the total quantity needed for each treatment was mixed and delivered to the assigned pens. The 4 diets were analyzed weekly for DM content (100°C forced-air oven for approximately 18 h). Samples were subsequently composited for the various weigh periods and analyzed for CP, ash, ADF, Ca, and P in the Texas Tech University Ruminant Nutrition Laboratory (AOAC, 1990; Table 1).

Cattle were weighed individually at approximately 28-d intervals. The trial ended on d 154 for 28 of the 40 pens (blocks 4 through 10), with the remaining pens fed for 177 d. On d 154 and 177, steers were weighed individually and then shipped to a USDA-inspected slaughter facility in Plainview, TX, for collection of carcass data. Carcass data were collected by personnel of the Beef Carcass Research Center at West Texas A&M University, and measurements included HCW, LM area, marbling score of the split-lean surface at the 12th-13th rib interface, percentage of KPH, fat thickness, calculated USDA yield grade, and USDA quality grade. Dressing percent (average = 63.13%) was used to calculate carcass-adjusted final BW from HCW and to subsequently calculate carcass-adjusted ADG and G:F.

The quantity of feed offered was recorded daily throughout the trial, and dietary DM measurements were used to determine DM offered to each pen. At the end of each weigh period, feed bunks were swept, and any feed remaining was weighed, analyzed for DM content, and subtracted from the total quantity of feed DM offered to the pen. Pen records for average BW and feed consumption were used to calculate ADG, DMI, and G:F for each weigh interval and for the total duration of the trial. Dietary NE_m and NE_g concentrations were calculated (NRC, 1996) from DMI and live weight-basis BW data with a 4% shrink.

A subsample of 4 blocks (4 pens/treatment) was monitored visually for feeding intensity and rate of feed consumption. Feeding intensity measurements were collected by a scan sampling technique. Sixteen pens of cattle were scanned to provide a visual assessment of feeding activity every 10 min, beginning at approximately 0700 and ending at approximately 1900 on d 30, 32, 60, 63, 126, and 133. To monitor feeding activity changes over time, days on which pen scanning occurred were spread over the feeding period. Collection period 1 was defined as before reimplant and consisted of collection d 30 and 32 as replications. Collection period 2 was defined as reimplant, consisting of collection d 60 and 63 as replications. Similarly, collection period 3 was defined as after reimplant and consisted of collection d 126 and 133 as replications. Feeding intensity was recorded as the number of steers present at the feed bunk, with their head down in the bunk or standing and masticating feed, at the time of the scan. Rate of feed consumption was measured on the 16 pens on d 31, 42, 54, 58, 128, and 135. On these days, feed remaining in the bunk was weighed at approximately 0700 and then placed back in the bunk. Total feed offered to the pens was calculated by the addition of feed remaining from the previous day plus newly offered feed. Feed disappearance was measured by reweighing the feed in each pen at 1 h after feeding and every 2 h thereafter for the next 10 h, resulting in 7 collection times per collection day. The number of steers present at the bunk per 10-min scan interval and the percentage of feed remaining at various collection times were calculated for each pen.

Exp. 2

Yearling crossbred steers (n = 1,983; average initial BW = 339 ± 1.15 kg) obtained through commercial market channels in Kansas, Oklahoma, and Texas were used in a randomized complete block design experiment conducted at the Cactus Research Ltd. facility located within the Cactus Feedyard at Cactus, TX, approximately 113 km north of Amarillo, TX. Four dietary treatments were evaluated in the study (DM basis; Table 2), including the following: a standard SFC-based control diet containing 9% roughage (CON) and 3 SFC-based diets containing either 20% WCGF and 9% roughage (20W9.0), 40% WCGF and 9% roughage (40W9.0), or 40% WCGF and 4.5% roughage (40W4.5). As in Exp. 1, the sole source of roughage in the diets was chopped alfalfa hay. The WCGF replaced a portion (DM basis) of SFC, molasses, and supplemental protein in the diet. All finishing diets were formulated (DM basis) to contain approximately 14% CP. Pelleted supplements supplied minerals, and vitamins and feed additives (Rumensin and Tylan) were added via a microingredient machine.

Steers were allotted to the experimental pens by gate-cut drafts of not more than 10 animals each until pens were filled with the number required to provide each animal with the same linear feed bunk space and area of pen surface. Cattle were stratified by source during allotment to pens. Final allotment consisted of animal counts that ranged from 90 to 113 steers/pen to the 4 treatments, with 5 pens/treatment. Treatments were assigned randomly within successive blocks of 4 adjacent pens. The soil-surfaced pens used in the trial were typical of the area, with mounds, fence-line feed bunks, and water troughs. All pens were of similar design and construction but did not have identical dimensions, be-

Table 2. Composition and analyzed nutrient content (DM basis) of experimental diets in Exp. 2

	Treatment[1]			
Item	CON	20W9.0	40W4.5	40W9.0
Ingredient				
Steam-flaked corn	77.20	58.49	42.81	38.51
WCGF	—	20.10	39.90	40.10
Alfalfa hay	9.00	9.00	4.50	9.00
Molasses	1.80	—	—	—
Fat (tallow)	3.60	3.80	4.00	4.00
Supplement 1[2]	—	4.30	—	—
Supplement 2[3]	—	4.40	8.70	8.30
Supplement 3[4]	8.40	—	—	—
Additives[5]	—	—	—	—
Analyzed composition				
DM, %	80.60	75.80	71.20	71.30
CP, %	13.70	13.80	13.80	14.20
Ca, %	0.60	0.72	0.86	0.84
P, %	0.30	0.49	0.63	0.63
NPN, %	3.30	1.00	—	—
NDF, %	11.30	17.30	21.90	23.70

[1]CON = control; 20W9.0 = 20% wet corn gluten feed (WCGF) with 9% alfalfa hay; 40W4.5 = 40% WCGF with 4.5% alfalfa hay; 40W9.0 = 40% WCGF with 9% alfalfa hay.

[2]Supplement 1 contained the following (DM basis): 3.08% cottonseed meal, 15.00% feather meal, 17.66% peanut meal, 36.81% sunflower meal, 7.89% urea, 4.75% calcium carbonate, 4.54% dicalcium phosphate, 5.00% limestone, 4.60% sodium chloride, 0.0014% cobalt sulfate, 0.0278% copper sulfate, 0.001% ethylenediamine dihydroiodide, 0.0036% iron sulfate, 0.091% manganese sulfate, 0.2699% Se (0.06%), and 0.2734% zinc sulfate.

[3]Supplement 2 contained the following (DM basis): 11.52% rice hulls, 64.57% wheat middlings, 20.28% calcium carbonate, 3.50% sodium chloride, 0.0006% cobalt carbonate, 0.0856% copper carbonate, 0.0006% ethylenediamine dihydroiodide, and 0.0377% manganese oxide.

[4]Supplement 3 contained the following (DM basis): 11.22% feather meal, 50.00% sunflower meal, 0.36% wheat middlings, 1.49% ammonium sulfate, 12.90% urea, 10.13% calcium cake, 2.29% dicalcium phosphate, 6.78% limestone, 0.70% magnesium oxide, 3.58% sodium chloride, 0.0386% copper sulfate, 0.0006% ethylenediamine dihydroiodide, 0.0279% iron sulfate, 0.1808% manganese sulfate, 0.1233% Se (0.06%), and 0.1931% zinc sulfate.

[5]The following were added (DM basis) using a microweigh machine (Micro Chemical Inc., Amarillo, TX): Rumensin (Elanco Animal Health, Indianapolis, IN), 33 mg/kg; Tylan (Elanco Animal Health), 11 mg/kg; vitamin A, 3,307 IU/kg; and vitamin D, 331 IU/kg.

ing similar in length but varying in width. Immediately following allotment of animals to the pens, an initial BW for each pen was obtained by group-weighing the pen using a standard platform scale.

All cattle were processed during the first 3 d of the trial. At processing, each steer was identified with 2 uniquely numbered ear tags, implanted with Ralgro, administered an IBR vaccine (Rhone Merieux, Athens, GA), Vision-7 (*Clostridium chauvoei-septicum-novyi-sordellii-perfringens* types C and D bacterin toxoid; Bayer Animal Health, Kansas City, MO), a drench suspension containing 1,000,000 IU of vitamin A and 200,000 IU of vitamin D, and treated for parasites with Dectomax. Steers were reimplanted with Component TE-S (120 mg of trenbolone acetate and 24 mg of estradiol; Vet-Life, West Des Moines, IA) on d 64 or 65 of the study.

Three step-up diets (35, 27, and 18% roughage, respectively) were used to adapt the steers to the final treatment diets. Step-up diets for the 20% WCGF treatment contained 20% WCGF. For the 40% WCGF treatments, the 35 and 27% roughage diets contained 20% WCGF, whereas the 18% roughage step-up diet contained 30% WCGF. Each diet step was fed for 5 d with a 2-d transition to the next step. Cattle received the final finishing diets by d 21 of the study. Pens were fed twice daily, and feed bunks were managed to be clean and empty of feed at the time of the morning feeding. Cattle were fed to appetite, with the quantity of feed issued to each pen adjusted daily by appraisal of cattle reaction to feed deliveries and by the quantity of feed, if any, remaining in the bunk before the first feeding of the day. Cattle were group-weighed unshrunk on d 0, 64, and 143 of the study to determine an average BW. Cattle also were weighed individually unshrunk on d 0 and 64. The trial ended on d 143, and a 4% pencil shrink was applied to final pen scale weights for calculation of pen performance data.

Quantity of feed offered was recorded daily throughout the 143-d trial. A sample of each diet was analyzed daily for DM content (65°C forced-air oven for approximately 24 h), and an additional sample was frozen for further analysis. Frozen samples were composited at 3-wk intervals, and a subsample was submitted to a commercial laboratory (SDK Laboratories, Hutchinson, KS) for analysis of moisture, CP, NPN, NDF, ether extract, Ca, P, and K. Orts that were determined to be unfit for the cattle to consume were removed from the feed bunk, weighed, and analyzed for DM content. Total DM weight of the orts was subtracted from the total quantity of feed offered. Wet corn gluten feed used in the study was sampled at the point of origin, and laboratory analyses were performed by Cargill Inc. Intakes were expressed on a DM basis, and pen records of total BW gain and feed consumption were used to calculate ADG, DMI, and G:F.

On d 143 of the trial, cattle were slaughtered by pen within block at a USDA-inspected slaughter facility in Amarillo, TX, for the collection of carcass information. Personnel from the Beef Carcass Research Center used to collect carcass data for Exp. 1 were contracted to match individual animal identification numbers to the numbers assigned by the slaughter facility. Carcass measurements were subsequently obtained from data supplied by the slaughter facility and included HCW and quality and yield grades assigned to each carcass by USDA graders after carcasses had chilled for approximately 36 h. Carcass-adjusted final BW was calculated as follows: final average net live weight of the pen × (pen average dressing percentage/trial average dressing percentage for all treatments). Carcass-adjusted ADG was then calculated as: (carcass-adjusted final BW − initial BW)/days on feed. Carcass-adjusted G:F was the ratio of DMI and carcass-adjusted ADG. As for Exp. 1, dietary NE_m and NE_g concentrations were calculated (NRC, 1996) from performance data.

Statistical Analyses

Exp. 1. Performance data were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC) for a randomized complete block design. The effects of treatment and block were included in the model, and pen was the experimental unit. Block was considered a random effect in the model. The following orthogonal contrasts were used to test treatment effects: (1) CON diet vs. the average of WCGF diets, (2) linear effect of roughage level in WCGF diets, and (3) quadratic effect of roughage level in WCGF diets.

Feeding behavior measurements also were analyzed using the MIXED procedure of SAS, with pen as the experimental unit. Initial consumption rate values were calculated with the REG procedure of SAS, with the feed remaining (percentage of the total) throughout the day regressed on time. The slope of the feed disappearance line was considered to be an estimate of the rate of feed consumption. Consumption rate data were analyzed using repeated measures model with the MIXED procedure of SAS. The model consisted of the dependent variable rate of feed consumption and accounted for the effects of treatment, collection period, the treatment × collection period interaction, collection day nested within collection period, and the treatment × collection period interaction nested within collection day. The same 3 orthogonal contrasts used for performance data were used to separate treatment effects.

Feeding intensity (average number of steers present at the bunk per unit time) was calculated using an area under the curve procedure (Galyean, 1993) for each pen. Area under the feeding intensity curve was defined as: $\Sigma\,(n_i + n_p) \times (t_i - t_p)/2$, where n_i = the current number of animals present at the bunk feeding; n_p = the number of animals present at the bunk feeding at the previous collection time; t_i = the current collection time (min); and t_p = the previous collection time (min). Although the pens were fed only once daily, the animals exhibited a crepuscular feeding pattern, with peak feeding times represented by an initial intense feeding period from the time fresh feed was offered to approximately 1 h later in the morning, and a secondary intense feeding period beginning approximately 4 h before sunset in the evening. To examine the effects of diet type on feeding intensity, area under the curve was calculated for the initial intense feeding bout, scaling the data to a common feeding time and continuing through 60 min after feeding. Area under the curve also was calculated for the 4 h before sunset each evening of a collection day by using data scaled to represent time of day, because animals initiated the secondary feeding bout at approximately the same time each day regardless of initial feeding time. The feeding intensity curve data also were analyzed using the same repeated measures model and orthogonal contrasts described for rate of feed consumption data.

Exp. 2. Pen was the experimental unit for the analysis of finishing performance and carcass characteristics, and data were analyzed by the MIXED procedure of SAS for a randomized complete block design, with block considered a random effect in the model. The following orthogonal contrasts were used to test treatment effects: (1) CON diet vs. the average of the WCGF diets, (2) 20% WCGF diet vs. the average of the diets containing 40% WCGF, and (3) 4.5 vs. 9% alfalfa hay in diets containing 40% WCGF.

In both Exp. 1 and 2, the GLIMMIX procedure of SAS was used to analyze the proportion of cattle in each pen grading USDA Choice or greater. The model was the same as for performance data, with the same 3 orthogonal contrasts described for performance data used to evaluate treatment responses.

RESULTS

Exp. 1

Analyzed nutrient content was within normal limits of formulated values (Table 1). Crude protein content was slightly greater than formulated values, which most likely resulted from the CP value for SFC used in formulation (8.5%) being less than the actual CP of the corn used in the experiment (9 to 9.5% based on sampling during the experiment).

Finishing Performance. Final BW did not differ (P = 0.90) between steers fed the CON diet and the average of the WCGF diets; however, a linear (P = 0.04) increase in final BW was observed within the WCGF diets as roughage level increased from 0 to 9% (Table 3). Similarly, a linear (P = 0.03) effect of roughage level was observed for the carcass-adjusted final BW. As expected with the changes observed in BW, a linear effect (P = 0.01) of roughage level within the WCGF diets on ADG was observed for d 0 to end and carcass-adjusted ADG, with steers fed higher roughage levels having greater ADG. The largest difference in carcass-adjusted ADG was noted for the W0.0 diet, with a decrease in ADG of 7.7, 6.5, and 4.0% compared with the W9.0, W4.5, and CON diets, respectively. A linear effect of roughage level [d 0 to 56 (P = 0.07), d 0 to 112 (P = 0.01), and d 0 to end (P = 0.01)] within the WCGF diets was observed for DMI, likely because of the lower DMI of the WCG + 0.0 diet compared with the 4.5 and 9% roughage levels. Steers fed the CON diet had lower daily DMI for d 0 to end (P = 0.04) than the average DMI by steers fed the WCGF diets. Beginning with d 0 to 112 (P = 0.01) through d 0 to end (P = 0.03), G:F was greater for the CON diet vs. the average of the WCGF diets. A linear response in G:F was observed for d 0 to 56 (P = 0.06) for the effect of roughage level within the WCGF diets, but no effects (P = 0.46) of roughage level were noted for d 0 to 112 or d 0 to end. Based on the performance data, calculated values for NE_m and NE_g (Table 4) were 2.34 and 1.65, 2.24 and 1.56, 2.26 and 1.56, and 2.31 and 1.62 Mcal/kg of DM for the CON, W9.0, W4.5, and W0.0 diets, respectively, with both NE_m and NE_g concentrations differing (P < 0.01) for CON vs. WCGF diets

Table 3. Effects of different levels of roughage and wet corn gluten feed (WCGF) on performance of feedlot beef steers in Exp. 1

	Treatment[1]					Contrast P-value[2]		
Item	CON	W9.0	W4.5	W0.0	SE[3]	CON vs. WCGF	L	Q
Initial BW, kg	313.9	313.3	314.7	313.8	10.34	0.98	0.86	0.59
Final BW, kg	554.0	562.0	557.0	546.1	9.95	0.90	0.04	0.70
Adj. final BW,[4] kg	553.6	562.2	560.5	543.1	9.40	0.84	0.03	0.33
ADG, kg								
d 0 to 56	1.52	1.53	1.49	1.53	0.04	0.96	0.97	0.41
d 0 to 112	1.56	1.58	1.56	1.50	0.03	0.66	0.07	0.54
d 0 to end[5]	1.50	1.55	1.51	1.45	0.03	0.82	0.01	0.61
Adj. d 0 to end[4]	1.49	1.55	1.53	1.43	0.03	0.90	0.01	0.29
DMI, kg/d								
d 0 to 56	6.84	7.19	7.00	6.82	0.22	0.30	0.07	0.95
d 0 to 112	7.16	6.54	7.38	7.08	0.18	0.17	0.01	0.59
d 0 to end[4]	7.28	7.80	7.60	7.20	0.17	0.04	0.01	0.42
G:F								
d 0 to 56	0.222	0.214	0.214	0.225	0.005	0.31	0.06	0.24
d 0 to 112	0.219	0.211	0.213	0.213	0.005	0.01	0.46	0.77
d 0 to end[5]	0.206	0.199	0.199	0.201	0.003	0.03	0.46	0.82
Adj. d 0 to end[4]	0.206	0.199	0.202	0.199	0.004	0.08	0.92	0.37

[1]CON = control; W9.0 = 40% WCGF with 9% alfalfa hay; W4.5 = 40% WCGF with 4.5% alfalfa hay; W0.0 = 40% WCGF with no added roughage.

[2]Observed significance level for orthogonal contrasts: CON vs. WCGF = CON vs. the average of the 3 diets containing 40% WCGF; L = linear contrast of diets containing WCGF and different levels of alfalfa hay; Q = quadratic contrast of diets containing WCGF and different levels of alfalfa hay.

[3]Pooled SE of treatment means (n = 10 pens/treatment).

[4]Carcass-adjusted values. Adjusted (Adj.) final BW and Adj. d 0 to end ADG were calculated as HCW/average dress of 63.13% and [(HCW/average dress of 63.13%) − initial BW]/days on feed, respectively. Adjusted d 0 to end G:F was the ratio of daily DMI and Adj. d 0 to end ADG.

[5]Pens of steers were fed to a common end point in BW and visual degree of finish. Steers in blocks 4 through 10 were fed for 154 d, whereas steers in blocks 1 through 3 were fed for 177 d, resulting in an average of 160.9 d on feed.

and a linear ($P < 0.01$) increase with decreasing roughage level.

Carcass Characteristics. Carcasses of steers fed the CON diet did not differ ($P > 0.10$) for any carcass measurement compared with the average of carcasses of the WCGF-fed steers (Table 5). A linear effect of roughage level ($P = 0.03$) was observed for HCW, with carcasses of steers fed the W9.0 diet being the heaviest among the 3 WCGF diets. This effect would be expected because of the linear increase in final BW and overall ADG (Table 3) noted previously. A quadratic effect ($P = 0.05$) was observed for dressing percent within WCGF diets, with an increase in dressing percent for the W4.5 diets relative to the W9.0 and W0.0 diets. Quadratic responses to roughage level within the WCGF diets were observed for fat thickness ($P = 0.03$) and yield

Table 4. Calculated NE_m and NE_g concentrations (Mcal/kg of DM) of diets containing wet corn gluten feed (WCGF) in Exp. 1

	Treatment[1]					Contrast[2]		
Item	CON	W9.0	W4.5	W0.0	SE[3]	CON vs. WCGF	L	Q
NRC (1996)-based								
NE_m	2.18	2.11	2.15	2.18	—	—	—	—
NE_g	1.50	1.44	1.47	1.50	—	—	—	—
Performance-based								
NE_m	2.34	2.24	2.26	2.31	0.02	<0.01	<0.01	0.54
NE_g	1.65	1.56	1.56	1.62	0.02	<0.01	<0.01	0.14

[1]CON = control; W9.0 = 40% WCGF with 9% alfalfa hay; W4.5 = 40% WCGF with 4.5% alfalfa hay; W0.0 = 40% WCGF with no added roughage.

[2]Observed significance level for orthogonal contrasts: CON vs. WCGF = CON vs. the average of the 3 diets containing 40% WCGF; L = linear contrast of diets containing WCGF and different levels of alfalfa hay; Q = quadratic contrast of diets containing WCGF and different levels of alfalfa hay.

[3]Pooled SE of treatment means (n = 10 pens/treatment).

Table 5. Effects of different levels of roughage and wet corn gluten feed (WCGF) on carcass characteristics of feedlot steers in Exp. 1

	Treatment[1]					Contrast[2]		
Item	CON	W9.0	W4.5	W0.0	SE[3]	CON vs. WCGF	L	Q
HCW, kg	349.5	354.9	353.9	342.9	5.95	0.84	0.03	0.33
Dressing percent	63.11	63.17	63.53	62.78	0.28	0.86	0.22	0.05
LM area, cm^2	81.24	83.56	81.01	81.09	1.18	0.59	0.10	0.31
Fat thickness, cm	1.40	1.41	1.52	1.29	0.07	0.89	0.15	0.03
KPH, %	1.99	1.95	1.96	1.93	0.05	0.35	0.70	0.72
Yield grade	3.18	3.11	3.33	3.03	0.10	0.87	0.52	0.02
Marbling score[4]	402.6	388.5	411.2	393.0	12.2	0.72	0.79	0.17
Choice, %	44.00	48.00	53.00	38.00	8.09	0.58	0.53	0.28

[1]CON = control; W9.0 = 40% WCGF with 9% alfalfa hay; W4.5 = 40% WCGF with 4.5% alfalfa hay; W0.0 = 40% WCGF with no added roughage.
[2]Observed significance level for orthogonal contrasts: CON vs. WCGF = CON vs. the average of the 3 diets containing 40% WCGF; L = linear contrast of diets containing WCGF and different levels of alfalfa hay; Q = quadratic contrast of diets containing WCGF and different levels of alfalfa hay.
[3]Pooled SE of treatment means (n = 10 pens/treatment).
[4]300 = slight^0; 400 = small^0; 500 = modest^0.

grade (P = 0.02), with higher values in both cases for the W4.5 diet, which is consistent with the increased dressing percent with this diet.

Feeding Behavior. Analysis of the consumption rate data indicated no significant (P = 0.18) collection day × treatment interaction, suggesting that changes over time were similar among treatments. No differences (P = 0.66) were observed for consumption rate among the treatments (Figure 1). Feeding intensity data are shown in Figure 2. No treatment × collection period interactions were observed for the area under the first hour after feeding intensity curve (P = 0.71); therefore, treatment effects are reported as the average of the 3 collection periods (Figure 2). Neither linear (P = 0.94) nor quadratic (P = 0.41) effects were observed among the 3 treatments containing WCGF; however, cattle in the CON treatment had a greater (P < 0.01) area under the curve than cattle in the 3 WCGF treatments, indicating that more CON steers were at the feed bunk during this period. Despite this difference for the first hour after feeding, analysis of the area under the feeding intensity curve showed no differences (P > 0.10) among treatments for feeding intensity during the 4 h before sunset (data not shown).

Exp. 2

As with Exp. 1, analyzed nutrient content closely reflected formulated values (Table 2).

Finishing Performance. Final (d 143) BW tended to be greater (P = 0.14) for steers fed the WCGF diets than for steers fed the CON diet (Table 6). Likewise, carcass-

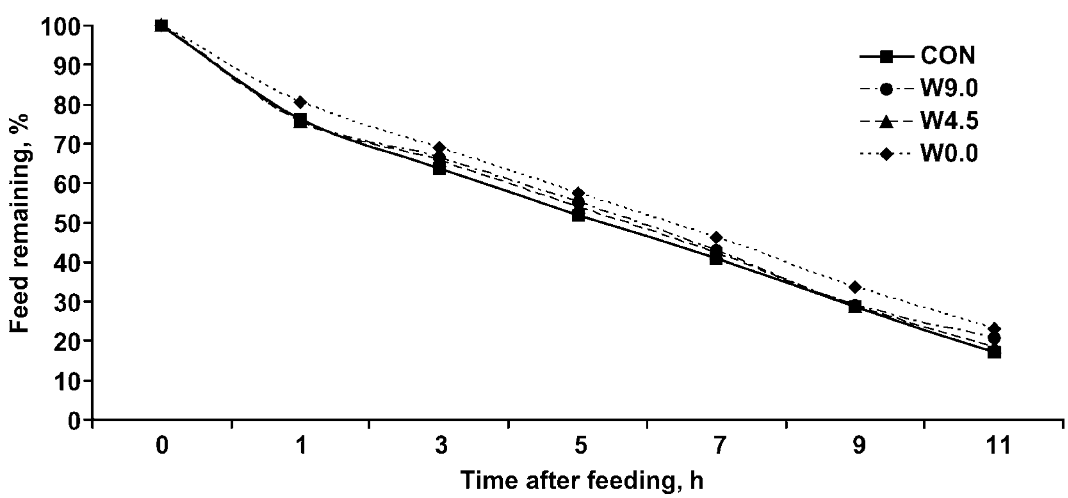

Figure 1. Effects of different levels of roughage and wet corn gluten feed (WCGF) on feed consumption rate (% of feed remaining/h) in Exp. 1. CON = control (slope = 6.90); W9.0 = 40% WCGF with 9% alfalfa hay (slope = 6.47); W4.5 = 40% WCGF with 4.5% alfalfa hay (slope = 6.79); W0.0 = 40% WCGF with no added roughage (slope = 6.76). Pooled SE = 0.25.

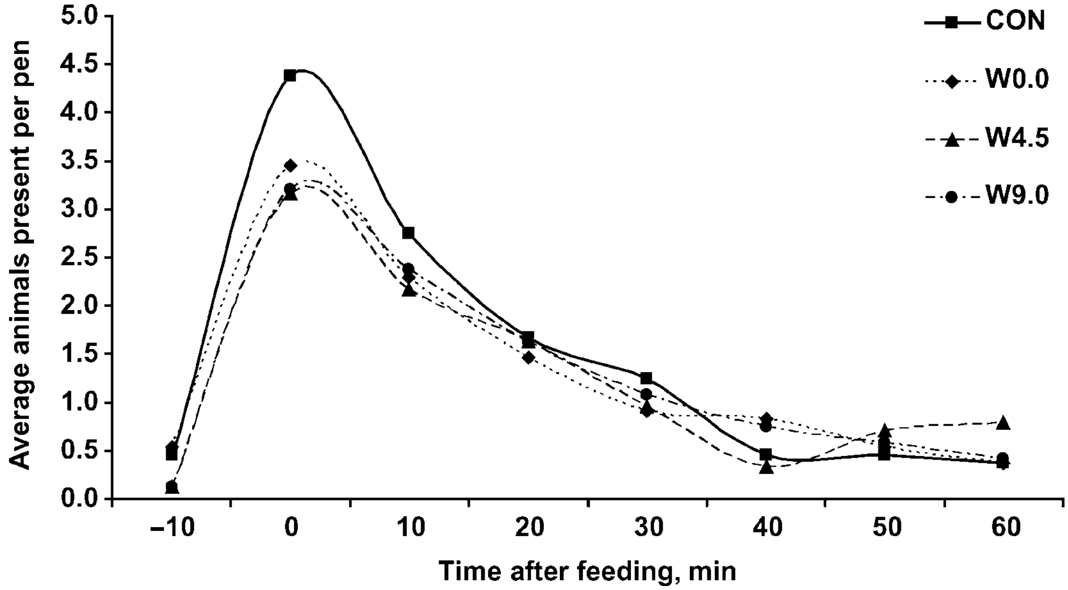

Figure 2. Effects of different levels of roughage and wet corn gluten feed (WCGF) on feeding intensity during the first hour after feeding in Exp. 1 (average of 3 collection periods). CON = control; W9.0 = 40% WCGF with 9% alfalfa hay; W4.5 = 40% WCGF with 4.5% alfalfa hay; W0.0 = 40% WCGF with no added roughage. Area under the curve was calculated for 0 to 60 min (data were scaled to a common feeding time), with an initial reading taken 10 min before feeding.

adjusted final BW was greater ($P = 0.02$) for steers fed the WCGF diets. Live weight-basis ADG (Table 6) tended to be less ($P = 0.08$) for steers fed the CON diet than for steers fed the WCGF diets, and carcass-adjusted ADG was less ($P = 0.01$) for CON steers. Average DMI was less ($P < 0.01$) by steers fed the CON diet than by steers fed the WCGF diets, and increasing roughage level increased ($P = 0.06$) DMI within the 40W diets. Live weight-basis and carcass-adjusted G:F were improved ($P < 0.01$) for steers fed the CON diet compared with steers fed the WCGF diets. In the 40W diets, decreasing the roughage level improved G:F (P

Table 6. Effects of different levels of roughage and wet corn gluten feed (WCGF) on performance of feedlot steers in Exp. 2

	Treatment[1]					Contrast P-value[2]		
Item	CON	20W9.0	40W4.5	40W9.0	SE[3]	CON vs. WCGF	20 vs. 40W	40W4.5 vs. 9.0
Initial BW,[4] kg	338.6	339.0	339.1	339.2	1.15	0.69	0.92	0.96
Final BW,[4] kg	573.7	579.4	578.5	578.5	2.88	0.14	0.80	1.00
Adj. final BW,[5] kg	570.9	582.6	577.4	579.1	2.75	0.02	0.22	0.68
ADG, kg								
d 0 to end[4]	1.64	1.68	1.67	1.67	0.02	0.08	0.64	0.97
Adj. d 0 to end[5]	1.62	1.70	1.67	1.68	0.01	0.01	0.11	0.59
DMI, kg/d								
d 0 to end	9.28	9.92	9.87	10.10	0.08	<0.01	0.53	0.06
G:F								
d 0 to end[4]	0.177	0.170	0.170	0.166	0.001	<0.01	0.08	<0.01
Adj. d 0 to end[5]	0.175	0.172	0.169	0.166	0.001	<0.01	<0.01	0.07

[1]CON = standard steam-flaked corn-based diet (n = 483); 20W9.0 = 20% WCGF with 9% alfalfa hay (n = 489); 40W4.5 = 40% WCGF with 4.5% alfalfa hay (n = 504); 40W9.0 = 40% WCGF with 9% alfalfa hay (n = 485).

[2]Pooled SE of treatment means (n = 5 pens/treatment).

[3]Observed significance level for orthogonal contrasts: CON vs. WCGF = CON vs. diets containing WCGF; 20 vs. 40W = the diet with 20% WCGF vs. the 2 diets with 40% WCGF; 40W4.5 vs. 9.0 = the effect of roughage level within the 40% WCGF diets.

[4]Initial (d 0) net live weight = mean scale weight on d 0 after randomization and physical allotment to pens with no pencil shrink. Final (d 143) net live weight = mean scale weight on d 143 with a 4.0% pencil shrink. Final adjusted (Adj.) BW = final net live BW × (pen dressing percent/trial average dressing percent).

[5]Calculated using the adjusted final BW.

Table 7. Calculated NE_m and NE_g concentrations (Mcal/kg of DM) of diets containing wet corn gluten feed (WCGF) in the diets fed in Exp. 2

	Treatment[1]					Contrast[2]		
Item	CON	20W9.0	40W4.5	40W9.0	SE[3]	CON vs. WCGF	20 vs. 40W	40W4.5 vs. 9.0
NRC (1996-based)								
NE_m	2.21	2.14	2.12	2.08	—	—	—	—
NE_g	1.51	1.46	1.44	1.41	—	—	—	—
Performance-based								
NE_m	2.04	1.97	1.97	1.93	0.008	<0.01	0.08	<0.01
NE_g	1.39	1.32	1.32	1.28	0.007	<0.01	0.09	<0.01

[1]CON = standard steam-flaked corn-based diet; 20W9.0 = 20% WCGF with 9% alfalfa hay; 40W4.5 = 40% WCGF with 4.5% alfalfa hay; 40W9.0 = 40% WCGF with 9% alfalfa hay.

[2]Observed significance level for orthogonal contrasts: CON vs. WCGF = CON vs. diets containing WCGF; 20 vs. 40W = the diet with 20% WCGF vs. the 2 diets with 40% WCGF; 40W4.5 vs. 9.0 = the effect of roughage level within the 40% WCGF diets.

[3]Pooled SE of treatment means (n = 5 pens/treatment).

< 0.01) and carcass-adjusted G:F ($P = 0.07$), and among the WCGF diets, cattle fed 20W9.0 had better G:F ($P = 0.08$) than the average of those fed the 40W diets. On a carcass-adjusted basis, steers fed the 20W9.0 diet also had greater ($P = 0.01$) G:F and carcass-adjusted G:F ($P = 0.01$) than steers fed the 40W diets. Using performance data, calculated values for NE_m and NE_g (Table 7) were 2.04 and 1.39, 1.97 and 1.32, 1.97 and 1.32, and 1.93 and 1.28 Mcal/kg of DM for the CON, 20W9.0, 40W4.5, and 40W9.0 diets, respectively. As in Exp. 1, NE_m and NE_g concentrations differed ($P < 0.01$) between the CON vs. WCGF diets. In addition, calculated NE concentrations tended to be greater ($P = 0.08$ to 0.09) for the 20W9.0 diet than for the average of the 40W diets, and decreasing roughage level in 40W diets increased ($P < 0.01$) calculated NE concentrations.

Carcass Characteristics. Hot carcass weights were less ($P = 0.02$) with the CON diet than with diets containing WCGF (Table 8). Within WCGF treatments, neither level of WCGF nor level of roughage affected HCW. Steers fed the CON diet had a lower ($P < 0.01$) dressing percent than steers fed the WCGF diets, and steers fed the 20W9.0 diet had a greater ($P = 0.01$) dressing percent than those fed diets that contained 40% WCGF. Decreasing roughage level in the 40W diets did not alter ($P = 0.23$) dressing percent. Yield grade of carcasses fed WCGF was greater ($P = 0.02$) than for carcasses of steers fed the CON diet. The percentage of cattle grading Choice was increased ($P = 0.02$) for steers fed the WCGF diets compared with those fed the CON diet. Moreover, among the WCGF diets, the percentage of cattle grading Choice was greater ($P = 0.01$) for the 20W9.0 diet than for the 40W diets.

DISCUSSION

The feeding of WCGF in SFC-based diets increased ADG when 4.5 to 9.0% roughage was supplied in Exp. 1. Likewise, ADG increased with added WCGF in Exp. 2 compared with CON. Overall, diets containing WCGF decreased G:F and increased DMI compared with CON diets. Similarly, Hussein and Berger (1995) showed that heifers fed WCGF diets had increased DMI, poorer feed efficiency, and little change in ADG compared with heifers fed conventional high-moisture corn-based diets. Sindt et al. (2003) also observed decreased G:F,

Table 8. Effects of different levels of roughage and wet corn gluten feed (WCGF) on carcass characteristics of feedlot steers in Exp. 2

	Treatment[1]					Contrast[2]		
Item	CON	20W9.0	40W4.5	40W9.0	SE[3]	CON vs. WCGF	20 vs. 40W	40W4.5 vs. 9.0
HCW, kg	365.4	372.9	369.6	370.7	1.79	0.02	0.21	0.67
Dressing percent[4]	63.70	64.36	63.89	64.07	0.10	<0.01	0.01	0.23
Yield grade	2.0	2.2	2.1	2.0	0.04	0.09	0.11	0.24
Choice, %	48.76	61.02	53.75	53.12	2.07	0.02	0.01	0.73

[1]CON = standard steam-flaked corn-based diet; 20W9.0 = 20% WCGF with 9% alfalfa hay; 40W4.5 = 40% WCGF with 4.5% alfalfa hay; 40W9.0 = 40% WCGF with 9% alfalfa hay.

[2]Observed significance level for orthogonal contrasts: CON vs. WCGF = CON vs. diets containing WCGF; 20 vs. 40W = the diet with 20% WCGF vs. the 2 diets with 40% WCGF; 40W4.5 vs. 9.0 = the effect of roughage level within the 40% WCGF diets.

[3]Pooled SE of treatment means (n = 5 pens/treatment).

[4]Dressing percent was calculated as mean HCW/mean actual net final live BW × 100.

increased DMI, and no effect on ADG when feeding SFC-based diets containing different combinations of WCGF and alfalfa hay. Dry matter intake tended to increase with increasing levels of WCGF; however, ADG did not differ for cattle fed all combinations of WCGF and alfalfa hay, and feeding increasing levels of WCGF resulted in a linear decrease in G:F (Sindt et al., 2003). Macken et al. (2004) observed a linear increase in DMI with increasing concentrations of WCGF; however, ADG and G:F did not differ among treatments. Although some research supports our results, other data on performance by finishing cattle fed DRC- and SFC-based diets containing WCGF are at variance with ours. Richards et al. (1998) indicated that DRC-based diets containing 25 or 50% WCGF increased ADG and decreased G:F. These results are similar to the results of the current study; however, Richards et al. (1998) did not observe differences in DMI by cattle fed the WCGF diets compared with the control diet. As in our Exp. 2, Loe et al. (2006) also observed increased DMI and ADG when feeding different combinations of WCGF and barley in finishing diets; however, G:F was not affected by dietary treatment in their study. Loe et al. (2006) observed that DMI and ADG peaked at 35 and 52% WCGF, respectively, levels similar to ours. Block et al. (2002) reported a quadratic effect for ADG and G:F for 0, 20, 30, and 40% WCGF (DM basis), with the optimal range from 20 to 30%. Based on the Block et al. (2002) data, it would be expected that the WCGF levels fed in the current study would increase G:F. Nonetheless, Block et al. (2005) observed increased DMI and ADG but little effect on G:F when WCGF was included in SFC-based finishing diets. Buckner et al. (2006) also reported increased DMI and ADG, with no changes in G:F, when feeding a 30% WCGF diet. Thus, there seems to be a fairly consistent response in increasing DMI and ADG when WCGF is added to finishing diets, with less consistent effects on G:F.

Results of Exp. 2 indicated that increasing levels of WCGF in SFC-based diets did not affect daily DMI or ADG; however, G:F was less for the average of the 40% WCGF diets than for the 20% WCGF, and G:F was greater for steers fed the CON diet than for steers fed diets containing either level of WCGF. Hussein and Berger (1995) indicated a similar response to increasing levels of WCGF in high-moisture corn-based diets, in which 25, 50, and 75% WCGF (DM basis) decreased G:F 3.5, 3.5, and 11.4%, respectively. Ham et al. (1995) reported that maximum intake and gain occurred when WCGF replaced 40% of the dietary DRC. In contrast to our results, Richards et al. (1998) indicated that calves fed 50% WCGF in DRC-based diets gained faster and more efficiently than calves fed a DRC control diet or a diet containing 25% WCGF.

Including WCGF in the diet did not affect carcass characteristics in Exp. 1. These data are consistent with most of the available data, which have not shown major changes in carcass characteristics when feeding WCGF (Macken et al., 2004; Block et al., 2005). In Exp. 2, however, WCGF diets improved quality grade, with an increased percentage of cattle grading USDA Choice for the WCGF diets compared with the CON diet. In addition, the 20% WCGF diet increased the percentage of cattle grading Choice compared with the average of the 40% WCGF diets. In the absence of additional carcass measurements like fat thickness LM area, it is difficult to determine the reasons for the increased percentages of cattle grading Choice.

The NE values calculated from performance were considerably greater than the NRC (1996) tabular values in Exp. 1 but less than tabular values in Exp. 2. For Exp. 1, the differences from tabular values might reflect greater NE values for SFC than the NRC (1996) values used for diet formulation (Table 4). Zinn et al. (2002) reported that steam-flaking increased the NE values of corn grain to values considerably greater than tabular values (15 and 18% for NE_m and NE_g, respectively). In terms of relative changes in NE_m and NE_g among treatments, however, performance-based values seemed generally consistent with what would be expected using NRC (1996) tabular values. For example, tabular NE_g values were 96, 98, and 100% of the CON diet for the 9, 4.5, and 0% roughage WCGF diets, respectively, whereas performance-based values for these same diets were 94.6, 94.6, and 98.2%, respectively, of the NE_g for the CON diet. For Exp. 2, environmental conditions or other unknown factors might have decreased performance-based NE calculations relative to tabular values. As with Exp. 1, however, percentage changes in NE_m and NE_g values relative to the CON diet were similar for tabular- and performance-based values.

Including WCGF in SFC-based finishing diets for finishing beef steers seemed to consistently increase DMI, possibly through decreasing acidosis (Block et al., 2005). From the data presented in Figure 2, there is evidence to suggest that the steers fed the CON diet had slightly different feeding behaviors than steers fed the WCGF diets. Conversely, the consumption rate data (Figure 1) showed no differences in the rate of feed consumption over the trial. These results are interpreted to suggest that the steers fed the CON diet had a more intense feeding pattern, as indicated by more animals present at the bunk feeding during the first hour after fresh feed was offered; however, their consumption rate was equal to that of the steers fed the WCGF diets, which had a significantly lower first-hour feeding intensity. One explanation for these seemingly conflicting data could be that the steers fed the WCGF diets consumed larger quantities, on a per-animal (or per bite) basis, than the CON steers. Previous research on the inclusion of WCGF to concentrate-based diets has indicated a decreased incidence in subacute acidosis compared with standard DRC-based diets containing no WCGF, likely because of the addition of highly digestible fiber to finishing diets (Krehbiel et al., 1995; Herold et al., 2000). Our feeding behavior measurements indicate that steers fed diets containing WCGF had less intense feeding bouts than steers fed the conventional SFC-based diets. Although steers fed WCGF had greater DMI, the seemingly decreased intensity with which they consumed feed might be advantageous, with regard to subacute acidosis, to their metabolic health and finishing performance. Thus, although the significance of these observations is not completely clear, these data indicate that feeding WCGF can somewhat alter feeding behavior over the course of a feeding period compared with a standard finishing diet based on SFC. We suggest that further investigation into the effects of WCGF on feeding behavior of feedlot cattle is warranted.

Wet corn gluten feed can be used effectively in feedlot diets, decreasing the need for most supplemental protein sources and molasses (and likely other conditioning agents), without negatively affecting ADG or carcass characteristics. Results of our 2 experiments indicated that WCGF included as 20 or 40% of dietary DM increased DMI and ADG, although it was potentially detrimental to G:F. Based on the results of Exp. 1, removing all the roughage from diets containing 40% WCGF would not be recommended. When included in SFC-based diets, WCGF decreased feeding intensity during the first hour after feeding, offering another possible explanation for the decreased incidence of subacute acidosis noted in previous research with WCGF.

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