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Evaluation of Nitrogen and Organic Matter Balance in the Feedlot as Affected by Level and Source of Dietary Fiber¹

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ABSTRACT: A trial was conducted to determine the effect of level and source of dietary fiber on N and OM excretion by cattle on finishing diets. One hundred twenty steers were stratified by weight and allotted to one of the following treatments: 7.5% roughage (7.5% R), wet corn gluten feed (WCGF; 41.5% of dietary DM), and all-concentrate (All Con) diet. Cattle were fed for 87 d during the summer with 23.7 m² of pen area per animal. Steers fed the WCGF diet had heavier final weights, greater DMI, and higher ADG ($P < .01$) than the 7.5% R and All Con treatments. Steers fed All Con had lower ($P < .01$) DMI than the other two treatments. Nitrogen and OM mass balances in the feedlot were quantified. Main components were nutrient input, retention, and excretion. Nitrogen and OM intake of steers fed WCGF

were greater ($P < .05$) than those of steers fed the other treatments. The WCGF treatment had a greater percentage of fecal N output ($P < .05$). The All Con treatment had a greater ($P < .01$) percentage of urinary N than WCGF and 7.5% R diets. Steers fed the WCGF treatment excreted more ($P < .01$) OM compared with the other treatments, which led to more N and OM being removed in manure at cleaning. The All Con treatment had more ($P < .01$) N and OM in runoff than the other treatments. Nutrition can change site of fermentation, which affects the composition of excreted material; however, total amount of N excreted may be more important than route of excretion in decreasing N losses to the environment and maximizing recovery in manure.

Key Words: Feedlots, Cattle, Manures, Nutrient Balance, Nitrogen, Fiber

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Introduction

Management practices must be developed that will maintain and protect the environment while permitting confinement feeding of beef cattle. Development of diets that alter the amount and route of N and P excretion can minimize deleterious effects of animal waste on the environment.

In ruminants, the degree of hindgut fermentation is affected by dietary carbohydrate sources, which affect the total amount of fecal N and OM (Giger-Reverdin et al., 1991; Larson, 1992). Carbohydrates are degraded extensively in the rumen and small intestine. Some sources of fiber do not digest extensively in the rumen but do ferment in the hindgut. Hindgut fermentation increases fecal N and decreases urinary N excretion (Ulyatt et al., 1975).

It has been estimated that 50 to 75% of excreted N is lost before feedlot pens are cleaned (Vanderholm, 1985; Eghball and Power, 1994), thus decreasing the nutrient value of the feedlot waste. Because urea is rapidly converted to ammonia following excretion (Mobley and Hausinger, 1989), and because 97% of urine N is urea (Mackie et al., 1998), shifting N excretion from urine to feces may lower ammonia losses from feedlots. The objectives of this study were to reduce the loss of N from the feedlot surface by shifting the distribution of N from urine to feces through dietary carbohydrate source and to evaluate retention and loss of excreted N and OM from the feedlot surface.

Materials and Methods

Digestibility Trial

Three British crossbred steers with average BW of 295 kg were studied in a 3 × 3 Latin square design. Steers were assigned randomly to one of three dietary treatments, 7.5% roughage (**7.5% R**), wet corn gluten feed (**WCGF**, 41.5% of DM), and all concentrate (**All Con**). Diets were formulated to contain a minimum of

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12.5% CP, .7% Ca, .3% P, .7% K, 11 mg/kg of Tylan (Elanco Animal Health, Indianapolis, IN) and 28 mg/kg of Rumensin (Elanco Animal Health; Table 1). Steers were adapted to each finishing diet in 21 d using four adaptation diets. Adaptation diets contained forage:concentrate ratios of 45:55, 35:65, 25:75, and 15:85. The forage source was a 50:50 mixture (DM basis) of corn silage and alfalfa hay, with corn silage assigned a forage value of 50%. Steers were given a 10-d adaptation period to the finishing diets followed by a 7-d collection period. Steers were housed individually in 1.5- × 2.4-m pens in a 25°C temperature-controlled room.

Steers were fed dietary treatments for 7 d in pens and then tied in stanchions for a 3-d adaptation period followed by 7-d total fecal and urine collection period. Feed intakes used for calculations were recorded 2 d before the collection period began and ended 7 d later. Total feces and urine were collected separately for 7 d. Steers were fed every 2 h by automatic feeders. Steers were fed near ad libitum intake, but DMI was managed to avoid accumulation of orts after each 2-h feeding. Orts that accumulated were weighed, sampled, and frozen at -4°C until they were analyzed. Fecal matter was collected in fecal collection bags. Urine was collected through rubber funnels strapped to the steers. Rubber tubing was connected to the bottom of the funnels and drained into plastic buckets placed in a pit below each steer. Urine was moved through the tubing by suction created by a vacuum. Urine was collected in a bucket containing 300 mL of 5 N sulfuric acid to prevent N volatilization. Twice per day, fecal bags were weighed, emptied, and 10% of feces was sampled. Once per day, urine buckets were weighed and contents were mixed and sampled. Feed ingredients were sampled during the collection period, and all fecal, urine, and feed samples were frozen at -4°C until they were analyzed.

All samples were composited by animal, treatment, and period then analyzed for Kjeldahl N (AOAC, 1996). Composited fecal samples were dried for 24 h in a forced-air oven at 60°C, ground through a 2-mm screen in a Wiley mill, and analyzed for DM (AOAC, 1996).

Data were analyzed as a Latin square design according to the GLM procedures of SAS (1990) with steer as the experimental unit.

Feedlot Trial

One hundred twenty crossbred yearling steers (336.6 ± .8 kg) were stratified by weight and randomly assigned to one of three dietary treatments. Steers were purchased the previous fall and back-grounded on cornstalks and drylot until May 27, 1994. Dietary treatments were the same as those described in the digestibility trial (Table 1). Steers were adapted to the final diets similar to the digestibility trial except that steers receiving 7.5% R and All Con

diets were fed the same adaptation diets with corn as the grain source and a 50:50 mixture of corn silage and alfalfa hay as forage sources, and steers receiving WCGF diets were fed adaptation diets with wet corn gluten feed replacing corn. Wet corn gluten feed (15.3% CP; 42.9% DM) was produced by Minnesota Corn Processors (Columbus, NE) and transported to the beef feedlot (Agricultural Research and Development Center, Mead, NE). Dietary feed ingredients were collected once weekly and frozen at -4°C until they were analyzed. Initial weights were the average of weights taken on two consecutive days after cattle had been adapted to finishing diets. However, to minimize variation in gut fill, a common diet was fed 5 d before initial weighing and feed intake was restricted to an estimated 2% (DM basis) of body weight. Steers were implanted with Revalor-S (Hoechst-Roussel, Warren, NJ) on the 2nd d that weights were taken. Steers were fed once daily with ad libitum

Table 1. Composition of diets used in digestibility and feedlot trials^a

Ingredient	Treatments ^b		
	WCGF	7.5% R	All Con
Dry-rolled corn	43.5	78.8	88.8
Wet corn gluten feed	41.5	—	—
Corn silage	5.0	5.0	—
Alfalfa hay	5.0	5.0	—
Molasses supplement ^c	—	6.2	6.2
Dry supplement			
Ground corn	2.72	2.45	1.92
Limestone	1.5	1.4	1.6
Urea	.32	.53	.64
Salt	.30	.30	.30
Potassium chloride	—	.19	.41
Animal fat	.10	.10	.10
Monensin premix ^d	.02	.02	.02
Tylosin premix ^e	.01	.01	.01
Vitamin premix ^f	.01	—	—
Trace mineral premix ^g	.02	—	—
Composition ^h			
Crude protein	12.47	12.92	12.83
Degradable intake protein	8.39	8.28	8.09
NDF	28.4	13.6	9.9
Calcium	.70	.70	.70
Phosphorus	.33	.25	.25
Potassium	.70	.70	.70

^aPercentage on a dry matter basis.

^bWCGF = wet corn gluten feed diet; 7.5% R = 7.5% roughage diet; All Con = all-concentrate diet.

^cUrea-based molasses supplement containing 50.6% CP, .55% P, vitamins (78,925 IU of vitamin A/kg, 15,789 IU of vitamin D/kg, and 20 IU of vitamin E/kg), and trace minerals (.37% of supplement DM; 2.25% Fe, 1.0% Zn, .64% Mn, .20% Cu, .18% Mg, .16% Co, and .55% I).

^d132 g monensin/kg of premix.

^e88 g of tylosin/kg of premix.

^f15,000 IU of vitamin A, 3,000 IU of vitamin D, and 3.75 IU of vitamin E/g of premix.

^g10% Mg, 6% Zn, 4.5% Fe, 2% Mn, .5% Cu, .3% I, .05% Co.

^hCrude protein and phosphorus were analyzed, other nutrients were calculated; all expressed as a percentage of diet DM.

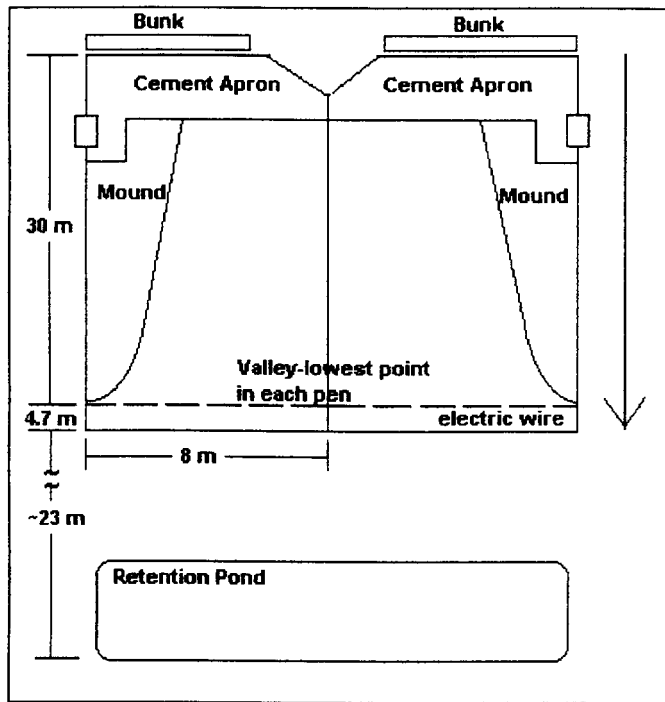


Figure 1. Diagrammatic representation of two test pens used for the 87-d collection period in the feedlot.

access to feed and water in outdoor pens. Cattle had 95 cm of linear bunk space and 23.7 m² of pen space per animal.

To minimize variation in gut fill, final weights were calculated from hot carcass weight assuming 62% dressing percentage. Fat thickness over the 12th rib and quality grade were recorded after a 48-h chill.

Cattle were adapted to treatment diets in pens not used during the collection period. Twelve pens used during the collection period were cleaned and remained idle for 30 d. Three soil core samples (15 cm deep) were taken from various locations within each test pen prior to cattle being placed into them. At the termination of the trial, test pens were cleaned, and three core soil samples were taken from approximately the same location within each pen.

After consuming the high-energy treatment diet for 7 d, steers were moved to the 12 test pens on June 27, 1994. Cattle performance data were based on the 118-d total feeding period including adaptation to high energy, whereas the nutrient balance data were based on the 87-d collection period while cattle were in the 12 test pens (Figure 1). The bottom of each pen was fenced off by electric wire to avoid build-up of waste material along the fence line where it could not be removed effectively. Pens were divided by one fence line on top of the mound and the other in the valley between mounds. Runoff from two adjacent pens was collected into one retention pond. The adjacent pens were assigned to the same treatment. Thus, six

retention ponds collected runoff from the 12 pens. Retention ponds were constructed of soil berms and lined with plastic.

Retention ponds were calibrated using a known volume of water. When a runoff event occurred, each retention pond's volume was quantified, the contents mixed manually, four samples taken, and then drained into the normal sediment basins for the feedlot. The retention ponds' maximal volume was approximately 80,000 L (40,000 L/pen). Weekly fecal samples from various areas in each pen were taken by hand and consisted of fresh fecal excrement without soil contamination. Soil cores, retention pond, and fecal samples were frozen at -4°C until they were analyzed.

Steers were fed for 87 d and then removed from pens. Pens were cleaned in replication across treatments immediately after the cattle were removed by removal of waste material with minimal soil. Material was piled on the apron in the pen with a front end loader with some manual cleaning using shovels. Material was mixed, sampled, and removed from the pen and weighed. In the last replication, pens (replication four for each treatment) did not get cleaned before it rained. After the rain subsided and the surface was fairly dry, runoff was collected from the retention ponds, and pens in the last replication were cleaned, sampled, and waste material was weighed.

Feed ingredients were collected weekly, dried at 60°C, and composited monthly. Fecal samples were composited by pen and oven-dried for 24 h at 60°C, ground through a Wiley Mill (2-mm screen), and analyzed for DM, Kjeldahl N, and ash (AOAC, 1996). Composited feed ingredients were also analyzed for Kjeldahl N and ash. Nutrient composition of feed ingredients (Table 2) was used to calculate nutrient intakes. Retention pond samples were analyzed for DM, Kjeldahl N, and ash. Samples of waste material from cleaned pens were mixed with 5 N sulfuric acid to allow particles to break apart. The material was thoroughly mixed, and a representative subsample was taken. Subsamples were analyzed for DM, Kjeldahl N, and ash.

Input of N was calculated as N concentration in the respective diet times DMI. Retained N was calculated using the net protein gain equation (NRC, 1996). The difference between N input and calculated N retention in the animal was total N excretion. The quantity of fecal N was calculated as DMI multiplied by DM indigestibility (from the digestibility trial, Table 3) multiplied by the concentration of N in the feces. Urinary N was determined by difference between total N output and fecal N output. Nitrogen removed from the feedlot surface was determined as the amount of manure DM removed at cleaning multiplied by the N concentration of the manure. Nitrogen lost in runoff

Table 2. Nutrient composition of dietary sources used in digestibility and feedlot trials^a

Ingredient	Nutrient				
	DM	N	P	OM	NDF ^b
Dry-rolled corn	86	1.39	.24	98.6	10.9
Wet corn gluten feed	43	2.44	.48	96.6	45.0
Corn silage	32	1.18	.18	94.9	48.0
Alfalfa hay	88	2.75	.27	90.9	46.0
Molasses supplement ^c	60	8.1	.55	95.1	—

^aDetermined by laboratory analysis, expressed as a percentage of dry matter.

^bTabular values.

^cUrea-based molasses supplement containing 50.6% CP, .55% P, vitamins (78,925 IU of vitamin A/kg, 15,789 IU of vitamin D/kg, and 20 IU of vitamin E/kg), and trace minerals (.37% of supplement DM; 2.25% Fe, 1.0% Zn, .64% Mn, .20% Cu, .18% Mg, .16% Co, and .55% I).

was calculated as the quantity of runoff multiplied by the N concentration of runoff. Nitrogen incorporated into the soil was the difference between 11.6 m³ (volume of soil in top 15 cm of each pen) multiplied by the N concentration of the soil following the trial vs the N concentration before cattle were in the pens. Amount of N volatilized was the difference between the amount of N excreted and the amount removed in manure, runoff, and N incorporated into the soil. Fecal OM equaled DMI multiplied by DM indigestibility (from digestibility trial, Table 3) multiplied by the concentration of OM in the feces.

Performance, carcass, and nutrient data were analyzed as a completely randomized design according to the GLM procedures of SAS (1990) with pen as the experimental unit. The experimental unit for runoff data was the retention pond. Therefore, runoff data were analyzed with two replications. Treatment was the model effect for all analyses. Mass balance data were analyzed based on the quantity of nutrients, expressed as kilograms per animal for the collection period (87 d).

Results and Discussion

Digestibility Trial

Nitrogen intake was lower ($P < .10$) for steers fed the All Con diet than for steers on the other two treatments (Table 3). Nitrogen excretion was greatest ($P < .10$) with the WCGF treatment and lowest with the All Con diet. Nitrogen digestibility was lower ($P < .10$) with steers fed WCGF than with steers fed 7.5% R and All Con. No treatment difference ($P > .10$) was observed between All Con and 7.5% R for N digestibility. Nitrogen excretion in feces was similar ($P > .10$) for WCGF and 7.5% R steers, with 50 to 55% of total N excreted in the feces. Steers fed the All Con diet excreted 33% of total N via the feces. Dry matter digestibility was lowest ($P < .10$) for WCGF and not significantly different between 7.5% R and the All Con treatment despite numerical differences.

Nitrogen intakes were different across dietary treatments due to differences in DMI and dietary N composition (Tables 1 and 2). Total N excretion was highest for WCGF and lowest for the All Con

Table 3. DM digestibility, N digestibility, and routes of N excretion from digestibility trial

Item	Treatment ^a			SEM
	WCGF	7.5% R	All Con	
DMI, kg	9.24	9.34	5.62	1.0
DM digestibility, %	71.4 ^b	80.5 ^c	83.5 ^c	2.3
N intake, g·steer ⁻¹ ·d ⁻¹	186.5 ^b	175.0 ^b	106.0 ^c	15.1
N excreted, g·steer ⁻¹ ·d ⁻¹ e	115.4 ^b	88.8 ^c	70.2 ^d	6.0
Fecal N, % of excreted	55.3 ^b	50.9 ^b	33.1 ^c	4.1
Urinary N, % of excreted	44.7	49.1	66.9	4.1
N digestibility, %	65.2 ^b	74.7 ^c	76.9 ^c	2.6
N indigestibility, %	34.8	25.3	23.1	2.6

^aWCGF = wet corn gluten feed diet; 7.5% R = 7.5% roughage diet; All Con = all-concentrate diet.

^{b,c,d}Means within a row with unlike superscripts differ ($P < .10$). Trends are similar between fecal and urinary N excretion percentages. Indigestibility was calculated as 100 minus digestibility.

^eTotal excreted calculated from measured urine and fecal output.

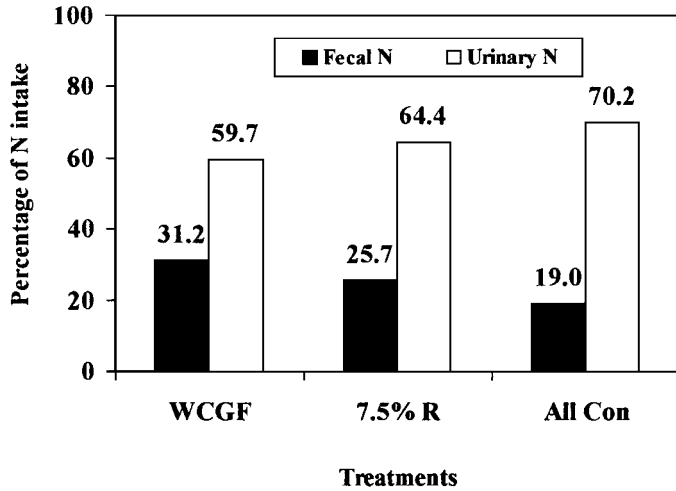


Figure 2. Distribution of excreted N between feces and urine as determined during the feedlot trial, where All Con = all concentrate, 7.5% R = 7.5% roughage from corn silage and alfalfa, and WCGF = 41.5% corn gluten feed with roughage. Values are expressed as percentage of N intake.

treatments. The high-starch diet probably reduced the amount of fermentable carbohydrate reaching the hindgut. The All Con treatment had the lowest fecal N excretion due to the low fiber content of the diet and, thus, had minimal hindgut fermentation (Larson, 1992). Hindgut fermentation of cellulose and hemicellulose accounts for 18 to 40% of total fiber digestion (Ulyatt et al., 1975). Therefore, feeding the WCGF diet resulted in greater ($P < .10$) fecal N excretion in grams/day, probably due to the hindgut fermentation.

The dietary treatments had different carbohydrate sources, and this caused variation in the distribution of excreted N between feces and urine. Mason et al. (1977) showed differences in the amounts of fecal and urinary N ($P < .01$) when sheep were infused with either cellulose, starch, or pectin, indicating that the

type of carbohydrate can influence the pathway for N excretion.

Urinary N accounted for 25 to 44% of the N intake. This range is slightly lower than yet agrees with the average (42.8%) determined by Giger-Reverdin et al. (1991), who fed 44 diets containing various carbohydrates to goats. When urinary N is expressed in grams of N per day, steers on all treatments excreted approximately the same amount, 44 to 52 g/d. Therefore, the primary difference between the dietary treatments seems to be the amount of fecal N excreted. The percentage of urinary N from this experiment may be low due to the difficulty in collecting 100% of the urine. If less than 100% of urinary N was collected, then N retention and the percentage of N intake excreted as fecal N would be overestimated. The percentage of N intake that was excreted as fecal N ranged from 22 to 34%, which is higher than results from the feedlot trial (Figure 2). However, the ranges of fecal N from both trials are in agreement with the average of 28.8% as determined by Giger-Reverdin et al. (1991).

Feedlot Trial

Steers on the WCGF treatment had higher ($P < .01$) final weights, DMI, and ADG than steers on the other two treatments (Table 4). Steers on the All Con treatment had the lowest ($P < .01$) DMI; however, those steers were the most efficient ($P < .01$). Steers fed 7.5% R were less efficient ($P < .10$) than the steers fed WCGF. Steers fed 7.5% R were intermediate in DMI ($P < .01$) and gain ($P < .10$). No differences were observed in fat thickness and quality grades.

Steers fed WCGF had greater ($P < .01$) N intakes than steers consuming 7.5% R and All Con diets. The N input differences result from the differences observed in DMI because N concentration in the diet was similar among treatments. Retention of N was greater ($P < .05$) in steers fed WCGF than in steers on the other two treatments (Table 5). Steers fed WCGF

Table 4. Dry matter intake, performance, and carcass characteristics of steers fed three finishing diets for 118 d

Item	Treatment ^a			SEM
	WCGF	7.5% R	All Con	
Initial weight, kg	337.2	335.9	336.7	.8
Final weight, kg	549.2 ^{b,e}	529.1 ^{c,f}	521.4 ^{c,g}	2.7
DMI, kg/d	12.32 ^b	11.59 ^c	10.41 ^d	.12
ADG, kg	1.80 ^{b,e}	1.64 ^{c,f}	1.57 ^{c,g}	.02
ADG:DMI	.146 ^{b,c,e}	.141 ^{b,f}	.151 ^{c,g}	.002
Fat thickness, cm	1.27	1.15	1.18	.05
Quality grade ^h	18.3	18.1	18.1	.24

^aWCGF = wet corn gluten feed diet; 7.5% R = 7.5% roughage diet; All Con = all-concentrate diet.
^{b,c,d}Means within a row with unlike superscripts differ ($P < .01$).
^{e,f,g}Means within a row with unlike superscripts differ ($P < .10$).
^hHigh Select = 18; Low Choice = 19.

Table 5. Nitrogen mass balance in the feedlot based on 87 d in collection pens

Criterion ^a	WCGF ^b		7.5% R ^b		All Con ^b		SEM, kg
	kg ^c	% ^d	kg	%	kg	%	
Input	22.92 ^e		20.53 ^f		18.27 ^f		.25
Retention	2.09 ^e		2.03 ^{ef}		1.98 ^f		.02
Excreted	20.83 ^e		18.50 ^f		16.29 ^g		.25
Feces	7.18 ^e	34.5	5.35 ^f	29.0	3.53 ^g	21.7	.37
Urine	13.65 ^e	65.5	13.15 ^e	71.0	12.76 ^f	78.3	.27
Removed	3.89 ^e	18.7	2.30 ^f	12.4	1.45 ^f	8.9	.27
Soil	2.06	9.9	3.03	16.4	2.38	14.6	.41
Runoff	.96 ^e	4.6	1.10 ^e	5.9	3.16 ^f	19.4	.27
Volatilized	13.92 ^e	66.8	12.07 ^e	65.3	9.30 ^f	57.1	.64

^aRetention = retention in the animal calculated from NRC equations; excreted calculated as difference between input and retention; feces = N excreted via feces calculated from DM excreted (from digestibility trial) multiplied by %N in composited fecal samples; removed = waste material removed from feedlot surface when pens cleaned; soil = balance of nitrogen in soil surface of pens.

^bWCGF = wet corn gluten feed; 7.5% R = 7.5% roughage diet; All Con = all-concentrate diet.

^cKilograms of N per animal while in collection pens.

^dAll values expressed as a percentage of N excreted.

^{e,f,g}Unlike superscripts within a row under the kilograms columns differ ($P < .01$).

excreted more ($P < .01$) total N than steers fed 7.5% R. Steers fed the All Con diet excreted the least ($P < .01$) total N when expressed as kilograms per animal. Based on DM digestibility determined in the digestibility trial and N concentration in feces for these three treatments, the steers fed WCGF excreted more ($P < .01$) N in the feces than steers in the other two treatments. Similarly, steers on the 7.5% R treatment excreted more ($P < .01$) N in the feces than steers on the All Con treatment. Because N excretion was greater with steers fed WCGF, N excretion in the urine expressed as kilograms per day was similar ($P > .10$) between WCGF and 7.5% R treatments despite a lower percentage of N excretion via the urine with the WCGF treatment.

Nitrogen removed in the manure followed a pattern similar to that of fecal N excretion: the most ($P < .01$) N was removed from pens of steers on the WCGF treatment. When expressed as a percentage of total N excreted, 18.7, 12.4, and 8.9% of excreted N was

removed in the manure for WCGF, 7.5% R, and All Con treatments, respectively. Nitrogen accumulating in the pen soil surface was not different ($P > .20$) among treatments; 10 to 16% of excreted N remained on the pen surface after cleaning. More N was lost ($P < .01$) from the pens on the All Con treatment in precipitation runoff.

Organic matter intake and excretion were highest ($P < .01$) with steers fed WCGF, intermediate with 7.5% R, and lowest ($P < .01$) with the All Con treatment (Table 6). Organic matter removed in manure followed a pattern similar to that for OM excretion: 28 to 35% of excreted OM was removed in manure. Loss of OM in runoff was similar ($P > .10$) for WCGF and 7.5% R, but more OM was lost ($P < .01$) from the All Con pens during runoff events.

The WCGF treatment had the greatest ($P < .01$) quantity and highest percentage of excreted nutrients (N and OM) removed in manure when the pens were cleaned. The quantity of waste material removed from

Table 6. Organic matter mass balance in the feedlot based on 87 d in collection pens

Criterion ^a	WCGF ^b		7.5% R ^b		All Con ^b		SEM, kg
	kg ^c	% ^d	kg	%	kg	%	
Input	1,059 ^e		981 ^f		854 ^g		12.0
Excreted	269 ^e		172 ^f		114 ^g		3.0
Removed	93.6 ^e	34.8	55.9 ^f	32.6	32.3 ^g	28.3	4.1
Soil	94.9	35.3	93.7	54.5	55.5	48.5	15.7
Runoff	7.1 ^e	2.7	6.3 ^e	3.7	19.1 ^f	16.7	1.8
Volatilized	73.3 ^e	27.2	15.8 ^f	9.2	7.5 ^f	6.5	15.4

^aExcreted calculated from DM excreted (from digestibility trial) multiplied by %OM in composited fecal samples; Removed = waste material removed from feedlot surface when pens cleaned; soil = balance of organic matter in soil surface of pens.

^bWCGF = wet corn gluten feed; 7.5% R = 7.5% roughage diet; All Con = all-concentrate diet.

^cKilograms of OM per animal while in collection pens.

^dAll values expressed as a percentage of OM excreted.

^{e,f,g}Unlike superscripts within a row under kilograms columns differ ($P < .01$).

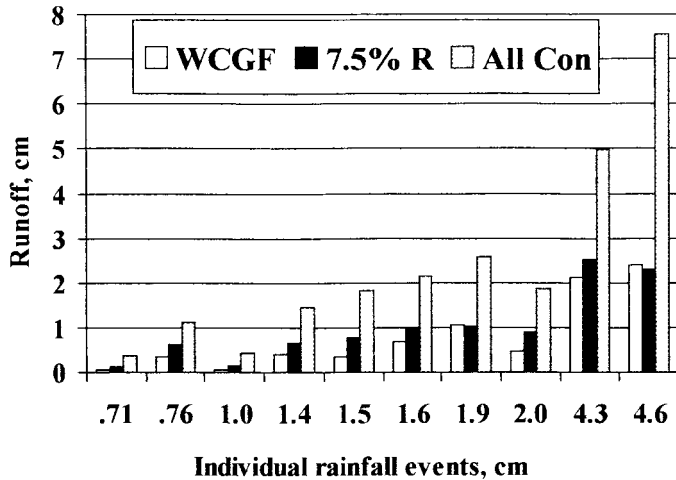


Figure 3. Quantity of runoff collected from pens during individual runoff events throughout 87 d while steers were in collection pens, where All Con = all concentrate, 7.5% R = 7.5% roughage from corn silage and alfalfa, and WCGF = 41.5% corn gluten feed with roughage. Pens on the All Con treatment had a greater quantity of cumulative runoff than pens on the WCGF ($P < .03$) and 7.5% R ($P < .09$) treatments.

the feedlot was greatest for the WCGF treatment due to the increased amount of fecal output. The quantity of material removed when the pens were cleaned included waste material on top of the surface plus some soil. The quantity of manure removed for the WCGF, 7.5% R, and All Con treatments were 232, 156, and 111 kg of DM per animal, respectively. The average quantity of material removed (166 ± 60 kg of DM per animal) was lower than the amount reported by Gilbertson et al. (1971), 318 kg of DM per animal. Gilbertson et al. (1971) fed a finishing diet and estimated digestibility as 75%, which is comparable to our WCGF treatment. Gilbertson et al. (1971) had a greater stocking rate than that in this study, 18.6 vs 23.7 m^2 per animal, and fed the cattle longer, 112 vs 87 d. When comparing OM removed at cleaning, Gilbertson et al. (1971) estimated 121 kg of OM by assuming that 87% of feces was OM, whereas, in our study 94 kg of OM was removed for the WCGF treatment.

The All Con pens had a greater ($P < .01$) quantity of cumulative runoff than the 7.5% R and WCGF pens. Nitrogen and OM in runoff from pens on the All Con treatment were greater ($P < .01$) than amounts in runoff from WCGF and 7.5% R pens when expressed as kilograms per animal. Pens on the All Con diets had the greatest quantity of runoff because the pens had less fecal material to "trap" rainfall on the surface. Pens of steers on the 7.5% R and WCGF treatments had a greater accumulation of fecal material on the feedlot surface, causing rainwater to pool. Variation in the quantity of individual runoff

events was due to differences in the quantity of precipitation and degree of soil saturation prior to rainfall (Figure 3). Runoff from pens on the All Con treatment during some runoff events exceeded the centimeters of rain and suggests that some runoff may have entered those pens from the feed alley. Those pens had a driveway upslope and during rapid precipitation may have had some water enter from the driveway. The 7.5% R and WCGF treatments resulted in 48.6 and 34.0%, respectively, of the precipitation resulting in runoff, this is in agreement with the 48% determined by Gilbertson et al. (1971) and the 36% observed by Clark et al. (1975). Significantly more runoff from the All Con treatment resulted in a higher percentage of nutrients in the runoff. The percentage of excreted N in runoff was 4.6, 5.9, and 19.4% for WCGF, 7.5% R, and All Con treatments, respectively. Percentage of excreted OM in runoff ranged from 2.7 to 16.7%. These percentages are in agreement with the 3 to 6% loss of excreted material in runoff reported by Gilbertson et al. (1971).

Steers consuming the WCGF diet had the greatest intake of nutrients due to greater DMI (Table 4). Subsequently, steers fed the WCGF diet excreted the most nutrients. Significantly more postruminal digestion of NDF occurs when a WCGF diet is fed compared to a dry-rolled corn diet (Larson, 1992). Thus, the higher fiber content of the WCGF diet apparently stimulated hindgut fermentation, causing an increase in the amount of fecal N excreted compared to 7.5% R and All Con diets. When expressed as a percentage of total N excreted, percentage of N in feces ranged from 21.7 to 34.5 and percentage of N in urine ranged from 66 to 78%; the WCGF treatment resulted in more fecal N and the All Con treatment resulted in more urinary N (Table 5). The proportion of excreted N in feces as a percentage of N intake (Figure 2) is lower than the distribution determined in the digestibility trial, probably due to difficulty in total collection of urine. If some urine was not collected, then the ratio in the feces would be overestimated. Therefore, the distribution of N in feces and urine in the feedlot trial is based on measured N content of fecal samples.

The amount of N removed from the feedlot surface when pens were cleaned was 17.0, 11.2, and 7.8% of N intake for the WCGF, 7.5% R, and All Con treatments, respectively. The values are lower than the 47 to 50% recovery of N input reported by Gilbertson et al. (1971) and Eghball and Power (1994). When the amount of N accumulated in soil was included in the quantity of N recovered, the percentage recovered was 26 for the WCGF and 7.5 R treatments and 21 for the All Con treatment. The discrepancy in recovery of N between this trial and past research may be due to the technique used to determine the values. In this experiment, the amount of excreted N was calculated using N intake and animal performance, whereas in the past the amount was estimated (ASAE, 1990).

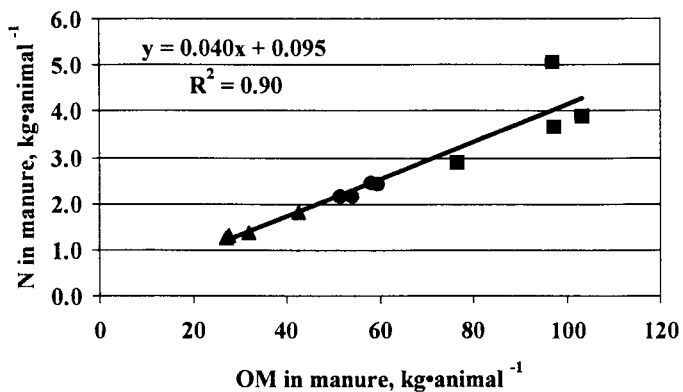


Figure 4. Relationship of manure N to manure OM expressed as kilograms/animal. ▲ = all concentrate, ● = 7.5% roughage from corn silage and alfalfa, and ■ = 41.5% corn gluten feed. Each point represents a pen average.

This experiment was conducted from June to October, whereas other research has addressed a full annual cycle. Recovery of N should be lower during the summer months due to greater ambient temperatures and better drying conditions (Hutchinson et al., 1982).

Volatilization losses were calculated by difference between the amount of nutrients excreted minus the amount removed from the pens, in the soil, and in the runoff. Overall, the WCGF treatment had a greater loss of N through volatilization because the pens were generally wetter than those of steers on the 7.5% R and All Con treatments. A wet feedlot pen causes the surface to be anaerobic, reducing the amount of nitrification and subsequently increasing volatilization of N as ammonia (Hutchinson et al., 1982). Another indicator of anaerobic conditions in the WCGF pens is the low percentage of N in the soil. Past research has shown that nitrification in the feedlot occurs under dry, aerobic conditions (Elliot and McCalla, 1973; Hutchinson et al., 1982). Nitrate content of soil samples was determined and represented less than .001% of the accumulated soil N for all treatments.

The significant amount of OM volatilized from pens on the WCGF treatment is probably related to the quantity of excreted OM. More OM was exposed to the environment and lost through volatilization. Regressing the amount of N recovered in manure with OM recovered in manure cleaned from the pens suggests a linear relationship between N retention in manure and amount of OM on the pen surface (Figure 4). The increased OM may lead to greater conversion of N from volatile forms such as ammonia to nonvolatile forms such as amino acids, similar to aerobic composting (Mackie et al., 1998). The percentage of excreted N that volatilized was 67, 65, and 57 for WCGF, 7.5% R, and All Con, respectively. The amount of N

volatilized per animal was greater for the WCGF and 7.5% R treatments than for the All Con ($P < .01$) treatment. Nitrogen excretion for the All Con and 7.5% R treatments was 4.5 and 2.3 kg less than that for the WCGF treatment.

Results from this experiment indicate that dietary fiber and carbohydrate source affect the amount of hindgut fermentation, resulting in different pathways for N excretion. The high NDF content of WCGF allowed more hindgut fermentation compared with the NDF content of 7.5% R and All Con rations. The amount of fecal N and OM excreted per animal was greatest for the WCGF treatment due to the higher DMI coupled with the effect of decreased digestibility. The WCGF diet caused the steers to excrete more fecal material, thus a greater quantity of nutrients were removed from the feedlot surface. The linear increase in OM in manure with increased fiber in the diet resulted in greater N retention in manure.

Implications

Waste management is a crucial part of feedlot operations. Most feedlots use waste material as a fertilizer for crops. Thus, maximum retention of nitrogen on the feedlot surface is important to ensure an acceptable fertilizer. Feeding corn gluten feed may be expected to increase fecal output and result in more nitrogen and organic matter available for use as fertilizer. Diet composition affects the amount and composition of excreted material. Fiber, in the form of corn gluten feed, corn silage, and alfalfa hay may triple (190% increase) organic matter removed in manure and increase the amount of nitrogen removed by 168%.

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