Digestibility of Dry-Rolled Corn, Wet Corn Gluten Feed, and Alfalfa Hay in Receiving and Finishing Diets

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Crude protein of wet corn gluten feed is degraded extensively in the rumen. Thus, protein supplementation is an important consideration when feeding wet corn gluten feed, especially in receiving diets.

Summary

Six ruminally-fistulated steers were used to evaluate ruminal metabolism and digestibility of dry-rolled corn, wet corn gluten feed, and alfalfa hay in receiving and finishing diets. In the receiving trial, ruminal digestibility of dry matter, crude protein, and starch was greater for wet corn gluten feed than dry-rolled corn. Apparent total tract digestibility of dry matter was greater for wet corn gluten feed diets

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compared with the dry-rolled corn diet. In the finishing trial, wet corn gluten feed increased ruminal pH and total tract fiber digestion.

Introduction

Wet corn gluten feed (WCGF) is an excellent energy source in diets for beef cattle. In forage-based growing diets, inclusion of WCGF supports performance superior to that observed when grain is included, presumably due to a reduction in negative associative effects. In finishing diets, reported energy values of WCGF range from 90 to 120 percent that of dry-rolled corn (DRC).

Wet corn gluten feed is comprised primarily of corn fiber (bran) and a liquid fraction. The liquid fraction contains steep liquor and may include condensed solubles from ethanol production. Compared with DRC, WCGF is much lower in starch (26 vs 72%, DM basis). Reducing dietary starch in finishing diets by replacing DRC with WCGF may reduce subacute acidosis, which may partially explain the higher energy value observed with WCGF. Additionally, WCGF is much higher in NDF (44 vs 12%, DM basis) than DRC. However, the NDF of corn bran is degraded rapidly and extensively in vitro. The CP content of WCGF is also higher than DRC (15 to 20 vs 9%, DM basis), but the majority of CP in WCGF is contributed by the liquid fraction and may be degraded extensively in the rumen.

The objective of these trials was to evaluate ruminal metabolism and digestibility of DRC, WCGF, and alfalfa hay in steers fed receiving and finishing diets.

Procedure

Receiving Trial

Six ruminally-fistulated steers (2 steers/treatment/period; 3 periods) were fed dietary treatments based on concentrate energy source (DRC or WCGF). Two sources of WCGF (WCGF1, Minnesota Corn Processors, Columbus, NE and WCGF2, Cargill, Eddyville, IA) were evaluated. Wet corn gluten feeds differed in the approximate proportions of bran to liquid (WCGF1, 70% bran:30% liquid, DM basis; WCGF2, 50% bran:50% liquid, DM basis). The DRC diet contained (DM basis) 45% alfalfa hay, 47.39% DRC, 6.09% molasses, .73% urea, and .79% vitamins and minerals. The WCGF diets contained (DM basis) 45% alfalfa hay, 54.39% WCGF and .61% vitamins and minerals. Diets were formulated to meet the degradable intake protein requirement (TDN× .13) and for a minimum of .7% Ca, .35% P, and 1.3% K. Steers were fed 12 equal portions daily (2-h intervals) and had ad libitum access to water. Feed allotment was such that feed intake was as close to ad libitum as possible.

Each period was 14 days — day one to nine for diet adaptation and day 10 to 14 for marker dosing, sample collection, and in situ incubation. Samples of ruminal fluid and contents were collected at 0, 4, 8, 16, and 24 hours after dosing. Fecal grab samples were collected at 24, 36, 48, 60, 72, 84, and 96 hours after dosing.

Ruminal fluid samples were analyzed for NH_3-N and VFA. Subsamples of each fecal sample were composited by steer, within period, for total tract digestibility calculations. Ruminal passage rates of DRC, WCGF1, WCGF2, and alfalfa hay were estimated from marker concentrations. Dry-rolled corn, WCGF1, and WCGF2 were marked with ytterbium and alfalfa hay was marked with erbium.

For in situ incubation, DRC was sieved to remove whole kernels and fine particles. Alfalfa hay was ground to pass through a 2-mm screen. Wet corn gluten feeds were incubated in the same form as they were fed. Approximately 5 g (DM basis) of material was placed into each polyester in situ bag. Bags were incubated for 0, 4, 8, 16, 24, 36, and 72 hours. Alfalfa hay was incubated in each steer; DRC and the WCGF were incubated in steers fed their corresponding dietary treatment. Following incubation, bags were removed, rinsed thoroughly, dried, and weighed. Samples were analyzed for CP, NDF, and starch to estimate rate of disappearance and ruminal digestibility. Ruminal digestibility (%) of DM, CP, NDF, and starch for each feedstuff was calculated using the following equation:

$$100 - ((k_p/(k_p + k_d)) \times (\% \text{ of original remaining after 0-hour wash}))$$

where k_p = rate of passage and k_d = rate of disappearance. Estimates were made using rates of passage determined from both ruminal and fecal samples. Diet and fecal samples were used to estimate total tract diet digestibility, with indigestible ADF used as an internal diet flow marker.

Finishing Trial

Steers used in the receiving trial were also used in the finishing trial (2 steers/treatment/period; 3 periods). Dietary treatments were based on concentrate energy source (DRC, DRC/WCGF, or WCGF). Wet corn gluten feed was produced by Minnesota Corn Processors, Columbus, NE. The DRC diet contained 83.08% DRC, 6.09% molasses, 7.5% alfalfa hay, 1.09% urea, and 2.24% vitamins and minerals. The DRC/WCGF diet contained 45.19% each of DRC and WCGF, 7.5% alfalfa hay, and 2.12% vitamins and minerals. The WCGF diet contained 89.89% WCGF, 7.5% alfalfa hay, and 2.61% vitamins and minerals. Diets were formulated to meet the degradable intake protein requirement (TDN × .081) and for a minimum of .7% Ca, .35% P, and .7% K. Diets contained (DM basis) .25% chromic oxide as a dietary flow marker. Feeding protocol was the same as described for the receiving trial.

Each period was 21 days — day one to nine for diet adaptation and day 10 to 21 for marker dosing, sample collection, and in situ incubation. A third week was necessary because DRC and WCGF were labeled with the same marker, thus it was not possible to estimate rate of passage of these feedstuffs simultaneously. Sampling and analysis of rumen fluid, rumen contents, and fecal samples were the same as described for the receiving trial.

In situ incubation protocol was the same as described for the receiving trial. During the second week, DRC was incubated in steers fed DRC, and WCGF was incubated in steers fed DRC/WCGF and WCGF. During the third week, DRC was incubated in steers fed DRC and DRC/WCGF. Sample analysis and calculation of ruminal digestibility were the same as described for the receiving trial. Diet and fecal samples were used to estimate total tract diet digestibility, with Cr used as a diet flow marker.

Results

Receiving Trial

Dry matter intakes were not different ($P > .10$) among treatments (Table 1). Experimental variation associated with ruminal passage estimates was lower with fecal samples compared with ruminal contents samples, thus only estimates using fecal samples are reported. Ruminal passage rates of both WCGF were faster ($P < .05$) than that of DRC. The faster passage rate of WCGF may be attributable to smaller particle size and(or) increased rumination activity in steers fed diets containing WCGF. Ruminal passage rate of alfalfa was slower ($P < .05$) for the DRC treatment than for either WCGF treatment. Again, rumination activity may have been greater in steers fed WCGF, resulting in more rapid particle size reduction and increased rates of passage. Ruminal pH and ruminal concentrations of NH_3-N, acetate, propionate, butyrate, and total VFA were not different ($P > .10$) among treatments (data not shown).

Rate of DM disappearance was faster ($P < .10$) for WCGF2 compared with DRC or WCGF1 (Table 1). Rates of CP and starch disappearance were fastest for WCGF2, intermediate for WCGF1, and slowest for DRC ($P < .10$). Nitrogenous compounds in WCGF are associated primarily with the liquid fraction, rather than the bran. Because the majority of CP in WCGF was solubilized during the 0-hour wash, presence of the soluble fraction cannot explain the more rapid rates of CP disappearance observed with WCGF. However, residual protein or starch associated with the bran fraction may be more susceptible to microbial degradation compared with starch and protein within the starch-protein matrix of corn. This would contribute to a more rapid rate of CP and starch disappearance. Rate of NDF disappearance was not different ($P > .10$) among concentrates. Rates of DM, CP, NDF, and starch disappearance of alfalfa were not different ($P > .10$) among treatments.

Table 1. Effect of dietary treatment on DMI, ruminal digesta passage, and rates of DM, CP, NDF, and starch disappearance in concentrate or alfalfa - Receiving Trial.

Item	DRC[a]	WCGF1[a]	WCGF2[a]
DMI, lb	21.8	22.5	23.4
Ruminal passage, %/hour			
Concentrate	4.9[b]	6.0[c]	5.8[c]
Alfalfa	3.9[b]	4.5[c]	4.4[c]
DM rate of disappearance, %/hour			
Concentrate	3.71[b]	4.05[b]	5.62[c]
Alfalfa	6.96	6.08	7.41
CP rate of disappearance, %/hour			
Concentrate	3.37[b]	5.55[c]	6.87[d]
Alfalfa	2.96	2.57	2.89
NDF rate of disappearance, %/hour			
Concentrate	3.20	3.07	3.78
Alfalfa	6.48	5.65	6.81
Starch rate of disappearance, %/hour			
Concentrate	4.63[b]	9.19[c]	11.27[d]
Alfalfa	2.58	2.42	2.63

[a]DRC = dry-rolled corn; WCGF1 = Minnesota Corn Processors, Columbus, NE; WCGF2 = Cargill, Eddyville, IA.
[b,c,d]Means within a row with unlike superscripts differ ($P < .05$).

Table 2. Effect of dietary treatment on ruminal digestibility of DM, CP, NDF, and starch in concentrate or alfalfa and apparent total tract digestibility - Receiving Trial.

Item	DRC[a]	WCGF1[a]	WCGF2[a]
Ruminal digestibility, %			
DM			
Concentrate	43.7[b]	59.2[c]	78.1[d]
Alfalfa	73.3[b]	68.2[c]	71.6[bc]
CP			
Concentrate	47.9[b]	81.6[c]	86.7[d]
Alfalfa	67.8[b]	62.8[c]	63.1[c]
NDF			
Concentrate	39.2[b]	33.8[c]	38.7[b]
Alfalfa	62.6[b]	55.9[c]	59.8[bc]
Starch			
Concentrate	43.9[b]	73.6[c]	88.8[d]
Alfalfa	62.1	59.6	62.5
Apparent total tract digestibility, %			
DM	56.0[b]	66.4[c]	64.5[c]
CP	49.5[b]	63.4[c]	59.5[bc]
NDF	65.7[b]	73.3[c]	69.3[bc]
Starch	67.1[b]	89.7[c]	86.5[c]

[a]DRC = dry-rolled corn; WCGF1 = Minnesota Corn Processors, Columbus, NE; WCGF2 = Cargill, Eddyville, IA.
[b,c,d]Means within a row with unlike superscripts differ ($P < .10$).

Ruminal digestibility of DM, CP, and starch was highest for WCGF2, intermediate for WCGF1, and lowest for DRC ($P < .10$; Table 2). We estimated that approximately 30 and 50 percent of the DM in WCGF1 and WCGF2, respectively, may have originated from the liquid fraction. These

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Table 3. Effect of dietary treatment on DMI, ruminal digesta passage, ruminal pH, and rates of DM, CP, NDF, and starch disappearance in DRC, WCGF, and alfalfa - Finishing Trial.

Item	DRC[a]	DRC/WCGF[a]	WCGF[a]
DMI, lb[bc]	16.3	20.5	18.7
Ruminal passage, %/hour			
DRC[d]	1.9	4.2	--
WCGF	--	5.2	5.4
Alfalfa	2.7	5.7	4.4
Ruminal pH[e]	5.49	5.71	5.77
DM rate of disappearance, %/hour			
DRC[d]	2.73	4.04	--
WCGF	--	2.56	2.71
Alfalfa[c]	2.75	5.03	5.25
CP rate of disappearance, %/hour			
DRC	1.96	2.31	--
WCGF	--	5.25	5.38
Alfalfa[f]	2.22	2.75	1.68
NDF rate of disappearance, %/hour			
DRC[d]	1.25	3.23	--
WCGF	--	1.39	1.56
Alfalfa	3.04	4.25	4.53
Starch rate of disappearance, %/hour			
DRC[d]	3.02	4.54	--
WCGF	--	9.07	8.82
Alfalfa	1.83	2.00	2.05

[a]DRC = dry-rolled corn; WCGF = wet corn gluten feed.
[b]Quadratic effect ($P < .05$).
[c]Linear effect ($P < .10$).
[d] 0 vs 50% ($P < .01$).
[e]Linear effect ($P < .05$).
[f]Quadratic effect ($P < .10$).

Table 4. Effect of dietary treatment on ruminal digestibility of DM, CP, NDF, and starch in DRC, WCGF or alfalfa and apparent total tract digestibility - Finishing Trial.

Item	DRC[a]	DRC/WCGF[a]	WCGF[a]
Ruminal digestibility, %			
DM			
DRC	52.2	49.3	--
WCGF	--	57.7	58.2
Alfalfa	74.5	59.5	66.0
CP			
DRC	40.7	38.8	--
WCGF	--	81.4	83.2
Alfalfa	59.7	54.7	53.2
NDF			
DRC	34.0	40.4	--
WCGF	--	16.6	18.9
Alfalfa	63.5	42.2	49.0
Starch			
DRC	52.2	47.9	--
WCGF	--	NE[b]	79.1
Alfalfa	75.6	66.2	69.7
Apparent total tract digestibility, %			
DM[cd]	83.4	77.7	79.7
CP	73.4	71.6	75.3
NDF[e]	61.8	66.2	73.6
Starch[f]	93.2	87.8	96.1

[a]DRC = dry-rolled corn; WCGF = wet corn gluten feed.
[b]NE = no estimate.
[c]Quadratic effect ($P < .05$).
[d]Linear effect ($P < .10$).
[e]Linear effect ($P < .01$).
[f]Quadratic effect ($P < .01$).

values are similar to the amount of DM solubilized during the 0-hour wash. Because the liquid fraction is soluble, it may be extensively digested in the rumen. Therefore, presence of the liquid fraction may contribute to the higher digestibilities estimated for WCGF. Ruminal digestibility of NDF in concentrate was higher ($P < .10$) for DRC and WCGF2 than for WCGF1. There is no clear explanation for the lower digestibility of NDF in WCGF1 compared with DRC and WCGF2.

Ruminal digestibility of DM in alfalfa was highest for calves fed DRC, intermediate for calves fed WCGF2, and lowest for calves fed WCGF1 ($P < .10$). Ruminal digestibility of NDF in alfalfa was highest for calves fed DRC, intermediate for calves fed WCGF2, and lowest for calves fed WCGF1 ($P < .10$). Ruminal digestibility of CP in alfalfa was higher ($P < .10$) for steers fed DRC compared with steers fed WCGF1 or WCGF2. The explanation for these observations is not clear. Ruminal digestibility of starch in alfalfa was not different ($P > .10$) among treatments.

Apparent total tract digestibility of DM and starch was higher ($P < .10$) for WCGF diets compared with the DRC diet (Table 2). Total tract digestibility of NDF was higher ($P < .10$) for WCGF1 compared with DRC, with NDF digestibility of WCGF2 being intermediate ($P > .10$) to WCGF1 and DRC. Apparent total tract digestibility of CP was higher ($P < .10$) for WCGF1 compared with DRC, with CP digestibility of WCGF2 being intermediate ($P > .10$) to WCGF1 and DRC.

Finishing Trial

Dry matter intake increased (quadratic, $P < .05$; linear, $P < .10$; Table 3) with inclusion of WCGF. Rate of passage for DRC was slower ($P < .01$) for the DRC diet compared with the DRC/WCGF diet. This may be due, in part, to lower DMI. Rates of passage for WCGF and alfalfa were not affected ($P > .10$) by dietary treatment.

Ruminal pH (linear, $P < .05$) increased with inclusion of WCGF. Additionally, concentrations of acetate (linear, $P < .05$) and butyrate (linear, $P < .01$) increased with inclusion of WCGF, while concentration of propionate decreased (linear, $P < .05$; data not shown). Total VFA concentration and ruminal concentration of NH_3-N were not affected by dietary treatment ($P > .10$; data not shown).

Increasing dietary WCGF had no effect ($P > .10$) on rate of disappearance for DM, CP, NDF, or starch of WCGF (Table 3). Rate of disappearance for DM, NDF, and starch of DRC was faster ($P < .01$) for the DRC/WCGF diet compared with DRC diet. Rate of disappearance for DM of alfalfa increased (linear, $P < .10$) with WCGF. Rate of disappearance for CP of alfalfa responded quadratically ($P < .10$) to WCGF addition. Rates of disappearance for NDF and starch of alfalfa were not affected ($P > .10$) by dietary treatment.

No differences ($P > .10$) in ruminal digestibility of DM, CP, NDF, or starch were observed for DRC, WCGF, or alfalfa (Table 4). Apparent total tract digestibility of DM was 83.4% for the DRC diet, 77.7% for the DRC/WCGF diet, and 79.7% for the WCGF diet (quadratic, $P < .05$; linear, $P < .10$; Table 4). Total tract digestibility of NDF increased (linear, $P < .01$) with WCGF. A quadratic ($P < .01$) response was observed for apparent total tract digestibility of starch. Apparent total tract digestibility of CP was not affected by dietary treatment.

Results of this research indicate that WCGF, whether fed in receiving or finishing diets, is digested extensively in the rumen. With receiving diets, replacing DRC with WCGF may increase total tract digestibility of DM, resulting in improved feed efficiency. In finishing diets, inclusion of WCGF increased ruminal pH. As a result, the efficiency of microbial protein synthesis may increase, potentially offsetting the need for escape protein supplementation when WCGF replaces DRC.

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