Effect of processing of supplemental corn on metabolizable protein of beef cows consuming low-quality forage[1]

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INTRODUCTION

Supplementation is required to offset nutrient deficiencies and to ensure optimal performance of cattle consuming low-quality forages (Caton and Dhuyvetter, 1997). Corn is frequently supplemented at low levels to offset energy deficiencies (Chase and Hibberd, 1987; Pordomingo et al., 1991; Carey et al., 1993). However, forage intake and digestibility may be negatively affected by the addition of corn or other cereal grains as a result of negative associative effects (Chase and Hibberd, 1987; Sanson et al., 1990; Pordomingo et al., 1991). The negative associative effects between corn grain and mature low-quality forage are possibly caused by exacerbating the rumen ammonia deficiency (Chase and Hibberd, 1987) by the fast fermentation of starch. Processing grain is used to optimize starch or energy availability by maximizing the extent of carbohydrate digestion in the rumen while controlling its rate of digestibility (Koenig et al., 2003). However, the effects of processing cereal corn on forage intake, digestion function, rumen fermentation, and metabolizable protein of cattle consuming low-quality hay have not been studied. Steam-flaking corn improves starch availability as a compared to dry-rolled corn (Zinn et al., 1995). Therefore, it is hypothesized that cereal corn-processing methods that increase rate of ruminal starch fermentation will negatively impact forage intake and characteristics of digestion. Hence, steam-flaked corn (**SF**) may increase the negative effects of corn supplementation on forage intake and digestibility as compared to ground corn (**GC**). The objective of this experiment was to evaluate the effects of method of processing supplemental corn on forage intake, digestive function, metabolizable protein, and rumen fermentation.

MATERIALS AND METHODS

All procedures and experimental protocols were approved by New Mexico State University Animal Care and Use Committee. Six ruminally and duodenally cannulated Angus crossed breed cows (680 ± 47.1 kg of initial BW) were utilized in a crossover design to evaluate the effects of method of processing supplemental corn on forage intake and digestive function. Cows were maintained in individual pens (5 × 4 m) in a barn under continuous lighting and free access to fresh water. Cows were offered hay and corn at 0700 h. Hay was offered to ensure ad libitum intake and 10% feed refusal daily. Corn grain was supplemented at 0.2% of BW (as fed basis) and placed directly into the rumen through the ruminal cannula. Bluestem hay (*Bothriochloa ischaemum*; 5.7% CP, 69.4% NDF, and 11.49% ash, DM basis) was offered after corn supplementation. Before being fed, the hay was chopped in a tub grinder through a 3.81-cm screen

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(Bear Cat 5A; Western Bear Cat, Hasting, NE). Treatments consisted of 1) GC and SF.

Sample Collections

Each experimental period was 14 d in length, allowing 9 d for adaption to the diet and 4 d for sample collection. Forage and ort samples were subsamples daily during feed and composited by animal within period. Cow weights were recorded at the beginning and end of each experimental period. Chromic oxide (8 g), placed in gelatin capsules (Torpac Inc, Fairfield, NJ), was dosed intraruminally on days 6 to 14 at 0700 h and 1900 h. Duodenal (100 mL), and fecal (200 g; wet basis) samples were collected on days 11 to 14 in a manner to achieve a sampling point every 3 h in a 24-h cycle distributed across 4 d. Sample collection times were the following: day 11, 0700 and 1300 h; day 12, 0100 and 1900 h; day 13, 1000, 1600, and 2200 h; and day 14, 0400 h. Duodenal and fecal samples from each cow and within each collection period were composited independently for analysis.

On day 12 of each period, rumen fluid samples were collected via rumen cannula, using a suction strainer (Precision Machine Co. Inc., Lincoln, NE) at 0, 3, 6, 9, 12, 15, and 21 h after supplementation. A volume of rumen fluid (200 mL) was drawn, and the pH was measured immediately after collection using a portable pH meter and combination electrode (HI 9024; Hanna Instruments SRL, Palermo, Italy). A 25-mL sample of ruminal fluid was retained and 1 mL of 6 N HCL was added at a rate of 1 mL/25 mL. Samples were stored frozen (−20 °C) for posterior NH_3 and VFA analysis. On day 14 at 0900 h of each experimental period, a 2-kg sample of ruminal content was taken and 1 liter of 0.9% NaCl (wt/vol) was added for isolation of bacterial cells (Zinn and Owens, 1986), and analysis of OM, ash, and purines.

Laboratory Analysis

Forage, orts, GC, and SF were dried in a forced air oven (55 °C, 72 h) and ground to pass a 2-mm screen in a Wiley mill (Wiley mill model 4, Thomas Scientific, Swedesboro, NJ). Duodenal and fecal samples were composited by cow within period and lyophilized (VirTis Lyotroll; SP. Scientific, Gardiner, NY), and ground with a Willy mill. Forage, orts, GC, SF, duodenal, and fecal samples were analyzed for DM, ash, CP (Methods 930.15, 942.05, and 990.02 ,respectively; AOAC, 1997), and NDF using an Ankom 200 fiber analyzer (Ankom Technology Corp., Fairport, NY). GC, SF, duodenal, and fecal samples were analyzed for starch according to Herrera-Saldana and Huber (1989). Duodenal samples were analyzed for purines (Zinn and Owens, 1986) and ammonia (Broderick and Kang, 1980). Duodenal and fecal samples were analyzed for Cr (Hill and Anderson, 1958). Ruminal bacteria were isolated from the mixture of ruminal contents with saline solution. The ruminal contents were blended, and the mixture was strained through four layers of cheesecloth. Then, the fluid was centrifugated at 1,000 × *g* for 10 min to remove feed particles and protozoa. The supernatant was then centrifugated at 27,000 × *g* for 20 min to separate bacteria. The bacteria were precipitated in the pellet and the supernatant was discarded. Then, the pellet containing the bacteria was resuspended with saline solution (0.9/% of NaCl; wt/vol) and re-centrifuged at 27,000 × *g* for 20 min. Isolated bacteria was frozen, lyophilized, and analyzed for DM, N, ash, and purines as described above. The acidified rumen fluid samples were centrifugated at 27,000 × *g* for 20 min and supernatant was analyzed for ammonia as previously described, and VFA (Goetsch and Galyean, 1983).

Calculations

Microbial OM and microbial N leaving the abomasum were calculated using purines as a microbial marker (Zinn and Owens, 1986). OM fermented in the rumen was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and microbial OM reaching the duodenum. Feed N reaching the small intestine was considered equal to total N leaving the abomasum minus NH_3-N, and microbial N and, thus includes endogenous N additions. Microbial N efficiency was calculated as g of duodenal microbial N per kg of OM fermented in the rumen.

Statistical Analysis

Data were analyzed as a crossover design using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC). The model included supplemental corn, period, and cow. When significant ($P < 0.05$) F-statistics were noted, means where separated using LSD. The mixed procedures of SAS were used to analyze the ruminal fermentation data (pH, NH_3-N, and VFA) using split-split-plot design. Effects in the model included supplemental corn, period, and supplemental corn × period. The repeated effect was time for rumen fluid sample collection and cow within supplemental corn × period was used as the error term

Table 1. Effects of energy supplementation on intake and characteristics of digestion of beef cows consuming low-quality hay

Item	Supplemental corn		SE	*P* value
	Ground	Steam-flaked		
DM intake, g/d				
Hay	7,318	6,597	0.17	0.04
Supplement	1,179	1,200	—	—
Total	8,498	7,798	173.0	0.04
OM intake, g/d				
Hay	6,482	5,843	150.5	0.04
Supplement	1,155	1,182	—	—
Total	7,637	7,026	153.5	0.04
OM intake, g/kg of BW	11.7	10.6	0.30	0.07
CP intake, g/d	514	462	9.6	0.02
NDF intake, g/d	5,187	4,695	119.8	0.04
Starch intake, g/d	853	925	2.8	0.01
Flow to duodenum, g/d				
DM	4,145	4,080	70.9	0.55
OM	3,280	3,177	58.1	0.27
Microbial OM	714	716	15.5	0.93
Feed OM	2,566	2,461	49.5	0.2
NDF	1,571	1,519	96.7	0.72
Starch	327	109	20.8	0.01
CP	553	563	11.5	0.58
Microbial protein	353	354	7.4	0.93
Feed protein	199	207	4.8	0.27
Microbial protein efficiency[a]	17	18	0.3	0.11
True ruminal digestion, % of intake				
DM	61.8	59.1	1.36	0.23
OM	66.2	64.7	1.07	0.36
CP	60.8	54.3	1.43	0.03
Starch	61.7	88.5	2.52	0.01
Fecal excretion, g/d				
CP	245	225	4.1	0.02
OM	2,408	2,388	69.5	0.84
NDF	1,708	1,740	70.3	0.76
Starch	55	20	9.8	0.06
Total tract digestion, % of intake				
DM	65.4	63.1	0.67	0.07
OM	68.2	66.1	0.73	0.09
CP	52.1	51.2	0.46	0.25
NDF	66.8	63.0	1.39	0.11
Starch	93.6	97.8	136.40	0.02

[a]Microbial protein efficiency = duodenal microbial N, g.kg $^{-1}$ OM fermented in the rumen.

to test the effects of supplemental corn. Individual cow was the experimental unit in all analysis.

RESULTS AND DISCUSSION

Effects of energy supplementation on intake and characteristics of digestion of beef cows consuming low-quality hay are shown in Table 1. Hay DM intake and total DM intake were greater (P = 0.04) for GC than for SF. Also, intake of CP (P = 0.02) and NDF (P = 0.04) was greater and starch intake (P = 0.01) was smaller for GC than SF. Starch and DM content of GC were lower than that of SF which was the cause of the starch intake difference between treatments. The flow of nutrients to the duodenum ($P \geq 0.11$) was not affected by corn-processing method with the exception of starch that was greater (P = 0.01) for GC than SF, and therefore starch ruminal digestion was greater (P = 0.01) for SF. Microbial efficiency was not affected (P = 0.11) by corn-processing method. Total tract digestion of DM (P = 0.07), OM

($P = 0.09$), and NDF ($P = 0.11$) tended to be lower, while total tract digestion of starch was greater for SF than GC.

Ruminal pH, total VFA production, and ammonia concentration were not affected ($P \geq 0.18$) by corn-processing method. However, the proportion of acetate ($P = 0.01$; 74.4, and 71.7 ± 0.77 mol/100 mol) was greater, propionate ($P = 0.06$; 14.8, and 17.2 ± 0.81 mol/100 mol), and butyrate ($P = 0.05$; 7.2, and 8.3 ± 0.32 mol/100 mol) were smaller for GC than for SF.

In agreement with previous research, ruminal starch availability was greater for SF than GC (Zinn et al., 1995). Positive associative effects have been noted with corn supplementation at 0.2% of BW to cattle consuming low- or medium-quality hay, but negative associative effects with supplementation levels above 0.2% of BW (Chase and Hibberd, 1987; Sanson et al., 1990; Pordomingo et al., 1991). In the present study, negative associative effects were present for SF as compared with GC (decrease forage intake and digestibility). It has been proposed that feed intake is controlled by the action of propionate in receptors of the rumen wall (Baile and Forbes, 1974). Results from this experiment show that the lower intake was for the treatment with greater ruminal propionate concentration (SF). Also, it has been proposed that forage intake decreases because starch exacerbates the ruminal ammonia deficiency (Chase and Hibberd, 1987). However, ruminal ammonia concentration in the present experiment was lower (0.29 and 0.25 ± 0.02 mM) than the minimum required for optimal microbial synthesis (between 3 and 3.6 mM; Satter and Slyter, 1974). Also, it has been suggested that forage intake decreases with grain supplementation when ruminal pH falls below 6.2 (Mertens, 1977). However, in the present study, processing method of supplemental corn did not affect ruminal pH (6.75 and 6.77 ± 0.05 for GC and SF, respectively).

In summary, steam-flaking corn decreases forage intake and digestibility without affecting microbial protein synthesis and improves ruminal propionate production.

IMPLICATIONS

Results from this experiment imply that we should expect the same productivity of cattle supplemented with SF than cattle supplemented with GC with lower forage consumption.

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