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Effect of MIN-AD Ruminal Buffer and Roughage Level on Ruminal Metabolism and Extent of Digestion in Steers

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Summary

Six ruminally and duodenally cannulated steers were used in a metabolism experiment to determine effects of adding a ruminal buffer to diets containing increasing levels of roughage. Steers were fed high-concentrate diets containing 4.5, 9.0, or 13.5% alfalfa hay with or without 1.0% MIN-AD ruminal buffer. There were no differences observed in feed intake, ruminal metabolism, or total tract digestibility due to MIN-AD inclusion in the diet. Average pH increased and time below pH 5.6 and pH 5.3 decreased with increasing alfalfa level. Total tract digestibility decreased with increasing alfalfa level. Addition of MIN-AD to high-concentrate diets did not produce a response similar to increasing the roughage level in the diet.

Introduction

Modern beef cattle finishing diets routinely contain in excess of 85% concentrate. Feeding high levels of concentrate which contains rapidly fermentable starch increases energetic efficiency of a feedlot ration, but also predisposes cattle to metabolic disorders such as ruminal acidosis. Decreased DMI and ADG may result from mild acidosis, while more severe acidosis may cause prolonged reductions in DMI and ADG and possibly even death.

Roughages are included in high-grain finishing diets to reduce digestive and metabolic disorders. However, on an energy basis, roughages are one of the most expensive ingredients in the ration, and are therefore included in finishing diets at low levels. Ruminal buffers are added to beef feedlot diets in an attempt to prevent ruminal pH depression and fluctuation and ultimately acidosis. By providing for a more constant ruminal pH, buffers decrease fluctuations in DMI, and also allow for replacement of a portion of the dietary forage with a higher-energy feedstuff. The avoidance of intake-depressing digestive disorders should ultimately result in fewer days on feed.

The objective of this experiment was to determine effects of MIN-AD ruminal buffer and forage level on feed intake, ruminal metabolism, and extent of digestion in steers fed a high-concentrate diet.

Procedure

Six ruminally and duodenally cannulated Holstein steer calves (initial BW = 500 lb) were assigned randomly to one of six treatments in a 3 x 2 factorial, arranged in a 6 x 6 Latin square. Following a 21-day adaptation to a high-concentrate diet, steers were assigned to a treatment and received a different treatment in each period and received every treatment once over the course of the experiment for a total of six replications per treatment. Steers received either 4.5, 9.0, or 13.5% roughage with or without MIN-AD ruminal buffer (calcium magnesium carbonate; MIN-AD, Inc., Amarillo, Tex.) which was provided at 1.0% of the diet DM (Table 1). The concentrate portion of each treatment contained an 80:20 ratio of high-moisture corn and dry-rolled corn, and the roughage was provided as alfalfa hay. MIN-AD was provided as part of a dry supplement. All diets contained 0.25% Mg, 30.8 mg/kg Rumensin, and 11 mg/kg Tylosin. Steers did not receive an implant in this experiment.

Periods were 21 days in length (12-day diet adaptation and 9-day data collection) and all animals were fed for ad-libitum intake. Bunks were read once daily throughout each period at 0730 and feed offerings were adjusted accordingly for feeding at 0800. All feed refusals were removed, quantified, and sampled. Steers were individually fed in free stalls from days 1-12 and days 18-21 of each period. In the afternoon of day 12, steers were moved and tethered to individual metabolism stalls and were allowed to acclimate to these stalls overnight. Beginning on day 13, steers were fed in individual feed bunks suspended from load cells connected to a computer equipped with software allowing for continuous data acquisition. Feed weight in each bunk was recorded once every minute and continuously stored for each steer throughout the day. Feed intake measurements (days 13-18 of each period)

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Table 1. Composition of diets (% of diet DM).

	No MIN-AD			1.0% MIN-AD		
Ingredient[a]	4.5% Alf.	9% Alf.	13.5% Alf.	4.5% Alf.	9% Alf.	13.5% Alf.
High-moisture corn	65.2	61.6	58.0	65.2	61.6	58.0
Dry-rolled corn	16.3	15.4	14.5	16.3	15.4	14.5
Alfalfa hay	4.5	9.0	13.5	4.5	9.0	13.5
Limestone	1.45	1.29	1.14	0.91	0.75	0.59
Urea	1.05	0.93	0.80	1.05	0.93	0.80
MIN-AD	—	—	—	1.00	1.00	1.00
Potassium Chloride	0.48	0.36	0.23	0.49	0.36	0.24
Fine ground corn	0.36	0.78	1.20	0.03	0.44	0.85
Magnesium Oxide	0.13	0.12	0.11	—	—	—

[a]All diets included molasses (5.0%), Soypass (5.0%), salt (0.3%), tallow (0.13%), trace mineral (0.05%), Rumensin (0.02%), Tylan (0.01%), and Vitamin A,D,E (0.01%).

Table 2. Simple effects of MIN-AD ruminal buffer and alfalfa level on feed intake.

	No MIN-AD			1.0% MIN-AD				*P* Value		
Alfalfa (% of DM):	4.5	9.0	13.5	4.5	9.0	13.5	SEM	Alfalfa	MIN-AD	A*M
DMI, lb	14.0	15.4	14.9	14.9	14.0	15.1	0.8	0.55	0.94	0.12
Meals/day	6.19	5.62	5.89	5.75	6.57	5.32	0.46	0.18	0.99	0.13
DMI/meal, lb	2.26[b]	2.74[ab]	2.53[ab]	2.59[ab]	2.13[b]	2.84[a]	0.22	0.21	0.95	0.01
Time eating/day, min	503	603	537	572	564	557	42	0.23	0.61	0.12
Time/meal, min	81.2[c]	107.3[a]	91.1[abc]	99.4[ab]	85.8[bc]	104.7[a]	7.7	0.42	0.48	0.01

[abc]Means within a row with uncommon superscripts differ ($P < 0.05$).

Table 3. Main effects of alfalfa level and MIN-AD ruminal buffer on ruminal pH.

	Alfalfa, % of DM			MIN-AD, % of DM			*P* Value[a]		
Item	4.5	9.0	13.5	0	1.0	SEM	Alf. Linear	Alf. Quad.	MIN-AD
Average pH	5.41	5.52	5.58	5.53	5.48	0.04	0.01	0.70	0.31
Maximum pH	6.25	6.39	6.41	6.36	6.33	0.07	0.09	0.43	0.70
Minimum pH	4.92	4.95	5.02	4.97	4.96	0.03	0.05	0.56	0.72
pH change	1.33	1.44	1.39	1.39	1.37	0.08	0.53	0.36	0.86
pH variance	0.10	0.11	0.10	0.11	0.10	0.01	0.60	0.27	0.52
Time < 5.6	1015.4	853.0	778.0	834.3	930.0	62.5	0.02	0.56	0.20
Area < 5.6	360.8	276.3	252.2	269.6	323.3	35.3	0.05	0.48	0.20
Time < 5.3	613.7	450.9	393.3	439.8	532.1	65.3	0.03	0.49	0.22
Area < 5.3	114.2	76.2	74.8	77.1	99.7	18.6	0.12	0.37	0.26

[a]No differences ($P > 0.10$) due to MIN-AD inclusion x alfalfa level interaction.

included DMI, number of meals per day, average meal size, total time spent eating, and average meal length.

Also on day 13 of each period, submersible pH electrodes were placed into the rumen of each steer through the ruminal cannula and remained in place through the morning of day 18. Each pH electrode was encased in a weighted, four-wire metal shroud to keep the electrode in a stationary suspended position approximately 4 to 6 inches above the ventral floor of the rumen. Electrodes were linked directly to a computer equipped with data acquisition software to record ruminal pH every six seconds and average ruminal pH every minute throughout the pH data collection phase. On day 18 of each period the ruminal pH electrodes were removed and steers were returned to their respective free stalls. Ruminal pH measurements included average, maximum, and minimum pH, time spent below pH 5.3 and 5.6, area of pH below 5.3 and 5.6 (time below x magnitude below), pH variance, and magnitude of pH change. Ruminal samples were collected from each steer immediately before feeding on day 21, and 3, 6, 9, 12, 18, and 24 hours after feeding for VFA analyses.

Chromic oxide was used as an indigestible marker for estimating fecal output. Boluses containing 7.5 g chromic oxide were inserted through the ruminal cannula twice daily (0700 and 1900 h) from days 8-16. Fecal grab samples were collected 0, 6, and 12 hours post-feeding on days 14-17.

Data were analyzed as a 3 x 2 factorial treatment arrangement and Latin square experimental design using the Mixed procedure of SAS. Model effects were period, forage level, MIN-AD level, forage x MIN-AD interaction, and steer. Steer was considered a random effect. Least squares means were separated using the PDIFF statement in SAS when protected by a significant ($P < 0.10$) *F*-test. Forage level was analyzed for linear and quadratic responses.

Results

Intake Behavior

Intake data presenting the simple effects of MIN-AD inclusion, alfalfa level, and their interaction are presented in Table 2. An interaction between alfalfa level and MIN-AD inclusion was observed for DMI/meal as steers consuming the 13.5% alfalfa, 1.0% MIN-AD treatment had greater ($P < 0.05$) DMI/meal than those consuming either the 4.5% alfalfa, no MIN-AD treatment or the 9.0% alfalfa, 1.0% MIN-AD treatment. A similar interaction ($P < 0.05$) was observed with time spent eating per meal, as the steers consuming the 13.5% alfalfa, 1.0% MIN-AD treatment and the 9.0% alfalfa, no MIN-AD treatment spent more time eating per meal than steers consuming the 4.5% alfalfa, no MIN-AD treatment. This suggests the 4.5% alfalfa, no MIN-AD treatment produced some digestive disturbances that altered the normal intake behavior of these steers. There were no alfalfa level x MIN-AD inclusion responses ($P > 0.10$) for any other intake variable. Neither the main effect of alfalfa level nor the main effect of MIN-AD inclusion were significant ($P > 0.10$) for any of the measured intake variables. Dry matter intake ranged from 14.0 to 15.4 lb/day. Intakes were numerically higher with 1.0% MIN-AD and 4.5% alfalfa compared with no MIN-AD and 4.5% alfalfa; however, the opposite response was observed at the 9.0% alfalfa level with a 1.4 lb numerical decrease in intake when 1.0% MIN-AD was included in the diet.

Table 4. Main effects of alfalfa level and MIN-AD ruminal buffer on total tract digestibility and VFA production.

	Alfalfa, % of DM			MIN-AD, % of DM			*P* Value[a]		
Item	4.5	9.0	13.5	0	1.0	SEM	Alf. Linear	Alf. Quad.	MIN-AD
Total Tract Digestibility, %									
DM Digestibility	84.6	83.9	80.8	82.7	83.4	1.0	0.01	0.30	0.53
OM Digestibility	86.5	85.8	83.0	84.7	85.4	0.9	0.01	0.33	0.54
VFA Production									
Acetate, mM	47.5	49.7	52.0	49.0	50.5	3.4	0.17	0.97	0.58
Propionate, mM	34.3	40.3	30.3	33.3	36.7	3.6	0.30	0.03	0.29
Butyrate, mM	11.2	9.3	10.4	9.8	10.8	1.3	0.47	0.16	0.27
Total VFA, mM	100.0	105.1	99.3	98.4	104.6	7.3	0.92	0.36	0.27
Acetate:Propionate	1.38	1.23	1.72	1.47	1.38	0.24	0.08	0.02	0.62

[a]No differences ($P > 0.10$) due to MIN-AD inclusion x alfalfa level interaction.

Ruminal pH and VFA Production

There were no effects on ruminal pH due to either MIN-AD inclusion or MIN-AD x alfalfa level interaction; therefore all ruminal pH data are presented showing the main effects of alfalfa level and MIN-AD inclusion (Table 3). Ruminal pH averaged 5.53 and 5.48 with 0 and 1.0% MIN-AD, respectively, and ranged from 4.97 to 6.36 for the no MIN-AD treatments and from 4.96 to 6.33 for the 1.0% MIN-AD treatments. Average ruminal pH responded linearly ($P < 0.05$) to increasing alfalfa level, with the lowest ruminal pH observed at the 4.5% alfalfa level and the highest at the 13.5% alfalfa level. Maximum and minimum ruminal pH exhibited a response similar to that observed with average pH. The difference between the maximum and minimum pH (pH change) was fairly constant across alfalfa level, as was pH variance. A linear response ($P < 0.05$) due to alfalfa level was observed for time below pH 5.6 and time below pH 5.3. For both variables, the impact was greatest when steers consumed the 4.5% alfalfa treatments. Subacute acidosis is generally defined as a ruminal pH below 5.6. In this study, when steers consumed the 4.5% alfalfa treatments, they had a ruminal pH below 5.6 for 1,015 minutes per day, and ruminal pH below 5.3 for 614 minutes per day. This represents nearly 17 hours of the day that these steers experienced subacute acidosis, and over 10 hours per day were spent at a pH of less than 5.3. Time spent below pH 5.6 was reduced 16 and 23% when steers consumed diets containing 9.0 or 13.5% alfalfa, respectively. Area below pH 5.6 responded ($P = 0.05$) similarly to time below pH 5.6, while area below pH 5.3 exhibited a similar decline with increasing alfalfa level; however, the response was not significant ($P > 0.10$). The area measurements represent the magnitude of pH depression multiplied by the time spent below the selected pH level.

There was little impact on VFA production due to alfalfa level, MIN-AD inclusion, or their interaction (Table 4). Total VFA measured 101.5 mM when averaged across all treatments. MIN-AD inclusion did not impact ($P > 0.10$) any measured VFA variable. Acetate production averaged 49.0 and 50.5 mM for the 0 and 1.0% MIN-AD treatments, respectively, while propionate production averaged 33.3 mM with no MIN-AD inclusion and 36.7 mM with 1.0% MIN-AD inclusion. A quadratic response ($P < 0.05$) due to alfalfa level was observed for propionate production, with the highest propionate levels observed when steers consumed the 9.0% alfalfa treatments. This quadratic response ($P < 0.05$) was also present with the acetate:propionate ratio, with the lowest ratio observed with the 9.0% alfalfa level.

Total Tract Digestibility

Total tract digestibility of DM and OM was calculated from estimated fecal output as measured by dosing of chromic oxide. There were no differences ($P > 0.10$) observed for either DM or OM total tract digestibility due to MIN-AD inclusion or MIN-AD inclusion x alfalfa level interaction (Table 4), with DM digestibility averaging 82.7 and 83.4% and OM digestibility averaging 84.8 and 85.4% for the 0 and 1.0% MIN-AD treatments, respectively. Total tract DM digestibility decreased linearly ($P < 0.05$) from 84.6 to 80.6% with increasing alfalfa level. Organic matter digestibility exhibited the same response ($P < 0.05$), with total tract digestibilities of 86.5, 85.8, and 83.0% when alfalfa was included in the diet at 4.5, 9.0, and 13.5%, respectively. The increase in alfalfa level in this experiment was in place of corn, which would explain the digestibility response.

In summary, ruminal metabolism and eating behavior were not impacted by the addition of MIN-AD ruminal buffer to steer diets. An increase in alfalfa level increased ruminal pH and decreased time spent at subacute pH levels, but also decreased OM digestibility. Additional analyses are yet to be completed to further evaluate the impact of MIN-AD in this study. Ruminal buffers are occasionally added to feedlot rations to mediate digestive disturbances without having to add roughage to the diet. In this study, however, the addition of MIN-AD to high concentrate diets did not produce responses similar to those produced by increasing the roughage level in the diet.

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