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Evaluation of Buffering Agents in Feedlot Diets for Cattle

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Feeding Acid Buf and sodium bicarbonate resulted in increased ruminal pH through rumen buffering and/or mediation of dry matter intake.

Summary

Six ruminally cannulated heifers were used in a 6 x 6 Latin square to determine effects of Acid Buf, sodium bicarbonate and Rumensin on severity of acidosis and feeding behavior when fed to cattle consuming high grain finishing diets. Heifers received diets containing no added buffer, Acid Buf at 0.75% or 1.25% DM, sodium bicarbonate at 1.25% DM, 28 grams/ton Rumensin, or 28 grams/ton Rumensin + 0.75% DM Acid Buf. Heifers were adapted to dietary treatments 9 days before a 5-day data collection period. Animals fed Acid Buf and sodium bicarbonate had a higher average ruminal pH. Feeding Rumensin and Acid Buf alone or in combination resulted in a lower DMI than no added dietary buffer. Ruminal VFA analysis yielded similar results among treatments.

Introduction

Ruminal acidosis is a major challenge when large amounts of rapidly fermentable starch is fed to beef cattle. Decreased DMI, decreased feed efficiencies and animal death (during acute acidosis) may result if acidosis is not properly managed. Animals experiencing acidosis can translate into severe economic loss. Methods of alleviating and/or reducing the incidence and severity of acidosis should be beneficial to the beef feedlot industry. Rumensin in high grain diets helps reduce acidosis (*1997 Nebraska Beef Report, pp. 49-52; 1999 Nebraska Beef Report, pp. 41-44*) presumably by mediating intake. Another option to reduce acidosis potential is adding buffer to the diet. One common buffering agent is sodium bicarbonate, but its use is variable due to its cost-benefit ratio. Another buffer, Acid Buf, has shown value in *in vitro* systems, *in situ* and sheep and dairy metabolism studies. However, continuous pH monitoring with associated feed intake in beef feedlot animals fed rapidly fermentable diets and fed buffers is limited and can offer insight into the potential of buffers to alleviate acidosis.

Our objective was to evaluate rumen buffer addition to the diet of grain fed animals based on ruminal pH, feeding behavior, rumen VFA concentrations, and water intake.

Table 1. Composition of diets (% DM basis)

Ingredient	CON	LOWBUF	HIBUF	RUM	RUM+BUF	BICARB
High-moisture corn	65.2	65.2	65.2	65.2	65.2	65.2
Dry-rolled corn	16.3	16.3	16.3	16.3	16.3	16.3
Alfalfa hay	7.5	7.5	7.5	7.5	7.5	7.5
Molasses, cane	5.0	5.0	5.0	5.0	5.0	5.0
Ground milo	2.57	2.43	2.33	2.55	2.41	1.59
Urea	1.13	1.14	1.14	1.13	1.14	1.16
Limestone	1.66	1.05	0.65	1.66	1.05	1.66
Salt	0.3	0.3	0.3	0.3	0.3	—
Tallow	0.24	0.24	0.24	0.24	0.24	0.24
Mineral premix[a]	0.05	0.05	0.05	0.05	0.05	0.05
KCl	0.04	0.04	0.04	0.04	0.04	0.04
Vitamin premix	0.01	0.01	0.01	0.01	0.01	0.01
Acid Buf®	—	0.75	1.25	—	0.75	—
Na-bicarbonate	—	—	—	—	—	1.25
Rumensin-80®	—	—	—	0.0194	0.0194	—

[a]Provided 70 mg Ca, 60 mg Zn, 40 mg Mn, 50 mg Fe, 7.5 mg Cu, 1 mg I, and 0.5 mg Co per kg diet DM.

Procedure

Six ruminally cannulated yearling crossbred beef heifers (avg. BW = 1094 lb) were used in a 6 × 6 Latin square to determine effects of sodium bicarbonate, Rumensin, and Acid Buf on rumen parameters and feed intake behavior. Dietary treatments were assigned randomly to animals and periods with six observations per treatment. Heifers were adapted over a 21-day period to the final finishing ration using four step-up diets (roughage level 45, 35, 25, 15% DM). The finishing diet (Table 1) was high moisture and dry-rolled corn based and contained 7.5% ground alfalfa hay (DM basis). Inclusion of Rumensin, Acid Buf, or sodium bicarbonate was achieved via the supplement (6% of diet DM). Dietary treatments were 1) 0 inclusion of Rumensin or buffers (CON); 2) Acid Buf at 0.75% DM (LOWBUF); 3) Acid Buf at 1.25% DM (HIBUF); 4) sodium bicabonate at 1.25% DM (BICARB); 5) Rumensin at 28 grams/ton (RUM);

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and 6) Acid Buf at 0.75% DM + Rumensin at 28 grams/ton (RUM+BUF).

Periods were 14 days in length (9-day diet adaptation and 5-day data collection) and all animals were fed to achieve ad libitum intake continuously throughout each period. Heifers were fed in individual free-stalls on days 1-8 of each period. On day 9, cattle were moved and tethered to individual metabolism stalls for a 1-day acclimation period before data collection (days 10 to 14). Bunks were read once daily throughout each period at 0730 hour and feed offerings were adjusted accordingly just prior to the once daily feeding at 0800 hour. Any feed refusals were removed, quantified and sampled. Heifers were fed individually while individual feed bunks were suspended from load cells connected to a computer equipped with software allowing continuous data acquisition. The feed weight in each bunk was recorded every minute and continuously stored for each heifer over the entire data collection period (days 10 to 14).

On day 10 of each period, submersible pH electrodes were placed into the rumen of each heifer through the ruminal cannula plug and remained until the end of the period (day 14). Each pH electrode was encased in a weighted, four-wire metal shroud to keep the electrode in a stationary suspended position approximately 5-10 inches above the ventral floor of the rumen. This allowed rumen contents to flow freely around the pH electrode. Electrodes were linked directly to a computer allowing data acquisition software to record a ruminal pH every 6 seconds and averaged for each minute throughout the days of collection for each heifer. A representative rumen fluid sample from each animal was also taken every 3 hours for a 24-hour period beginning on day 13 of each period. Rumen fluid samples were individually labeled and stored frozen until VFA analyses were conducted.

Water intake of each heifer also was quantified on days 10 to 14 of each period. This was obtained by suspending six individual water containers overhead. Water containers were monitored and filled when necessary to continuously supply water at all times. Water disappearance was recorded and water intake was calculated on a daily basis for each individual heifer assuming disappearance equates to consumption and no wastage. Our hypothesis was that cattle experiencing ruminal acidosis may consume water differently than those that are not, thus we wanted to measure the effect that rumen buffers would have on water intake.

Feed intake measurements (day 10 to 14) included DM intake, rate of intake, number of meals per day, average meal size, total time spent eating and average meal length. Rate of intake was calculated as a 1st order reaction following log transformation of DM disappearance from bunks. Meals were calculated from DM disappearance data and designated a meal when bunks did not change weight for a 10 minute interval. Ruminal pH measurements (day 10 to 14) included average, maximum and minimum pH, area of pH below 5.6 and 5.3 (time below x magnitude below), pH variance and magnitude of pH change.

Feed intake, water intake and ruminal pH data (days 10 to 14) were analyzed using the Mixed procedure of SAS for a Latin Square design. Model effects were period and treatment while animal was termed a random effect, thus placed into the random statement. Least squares means were separated using the PDIFF statement of SAS (Bonferonni t-test statistic) when protected by a significant ($P < 0.10$) *F*-test.

Results

Ruminal pH

Results for rumen pH data are reported in Table 2. Average pH, minimum pH and maximum pH for a 24-hour period all were influenced by diet treatment based on F-test statistic. Feeding Acid Buf at either level or BICARB increased average pH relative to control. On average, pH increased from 5.95 to 6.12 by feeding Acid Buf. Subsequently, minimum pH and maximum pH were also higher when buffers were fed as would be expected with higher average pH. Interestingly, magnitude of pH change and pH variance were not influenced by dietary treatment. Some of the common measurements to assess acidosis using our continuous data acquisition system are time and area of ruminal pH below 5.6 and 5.3. Area of ruminal pH below these points is related to both magnitude and time (minutes) spent below either 5.6 or 5.3. While these numbers are an average value, they tend to give insight into when cattle go "off feed." In this experiment, time (in minutes) was influenced by treatment. Rumen pH from cattle fed HIBUF and BICARB was below 5.6 for less time than CON fed heifers. Feeding LOWBUF was intermediate to HIBUF and CON but decreased time below 5.6. Data on area below 5.6, time below 5.3, and area below 5.3 support the observation that feeding buffers prevented both magnitude and time below pH of either 5.6 or 5.3.

Intake Behavior

Intake behavior and meal consumption data are presented in Table 3. A significant treatment effect was observed for DMI ($P = 0.02$). Feeding either Acidbuf or Rumensin alone or in combination resulted in lower DMI compared to CON fed heifers. Heifers consuming BICARB were intermediate in DMI compared to CON and Acid Buf treatments. There appeared to be an effect of level of Acid Buf on feed intake. As Acid Buf inclusion into the diet increased, there was a depression in consumption relative to CON fed heifers. The other intake behavior variables including rate of intake (% per hour), number of meals or meal size and time spent eating during the day or a meal were not influenced by dietary treatment. All variables had trends consistent with Rumensin and Acid Buf decreasing meal size and the average size of the largest meal. Perhaps the benefit of feeding Acid Buf is that meal size decreases and time spent eating increases. While not statistically significant, the consistent response across treatments for these variables may be "biologically significant," because of the effects that ruminal acidosis has on feed intake and subsequently animal performance.

Table 2. Effects of added Rumensin or dietary buffers on ruminal pH of heifers fed a high concentrate finishing diet.

	Dietary Treatment[1]							
Parameter	CON	LOWBUF	HIBUF	BICARB	RUM	RUM+BUF	SEM	*F*-Test
Average pH	5.95^{ab}	6.13^{cde}	6.11^{cd}	6.25^{e}	5.91^{a}	6.06^{bc}	0.14	<0.01
Minimum pH	5.34^{a}	5.51^{bcd}	5.53^{cd}	5.63^{d}	5.37^{ab}	5.42^{abc}	0.12	0.02
Maximum pH	6.65^{ab}	6.79^{cde}	6.75^{bcd}	6.88^{e}	6.59^{a}	6.74^{bc}	0.09	<0.01
pH change	1.31	1.28	1.23	1.25	1.22	1.32	0.07	0.75
pH Variance	0.120	0.110	0.108	0.113	0.118	0.135	0.02	0.76
Time < 5.6	406^{cd}	268^{abc}	237^{ab}	156^{a}	449^{d}	305^{abcd}	139	0.06
Area < 5.6	106	57	48	26	100	53	38	0.28
Time < 5.3	163	65	51	20	123	35	64	0.45
Area < 5.3	19.3	7.0	5.3	2.1	8.8	1.7	7.4	0.50

[1]CON= no added Rumensin or dietary buffer, LOWBUF= 0.75% DM Acid Buf, HIBUF= 1.25% DM Acid Buf, BICARB= 1.25% DM sodium bicarbonate, RUM= 28 grams/ton Rumensin, RUM+BUF= 28 grams/ton Rumensin and 0.75% DM Acid Buf.
[abcde]Means in a row with unlike superscripts differ ($P < 0.10$).

Table 3.Effects of added Rumensin or dietary buffers on feed intake and water consumption of heifers fed a high concentrate finishing diet.

	Dietary Treatment[1]							
Parameter	CON	LOWBUF	HIBUF	BICARB	RUM	RUM+BUF	SEM	*F*-Test
Intake								
DMI, lb/day	23.5^{e}	21.2^{abc}	20.0^{a}	22.0^{bcde}	20.9^{abcd}	21.0^{ab}	1.3	0.02
Rate, %/hour	25.3	25.2	22.7	27.7	25.2	25.0	2.3	0.75
Meals								
No./day	5.6	5.8	5.7	5.5	5.6	5.5	0.5	0.99
Avg., lb	6.65	5.87	4.90	5.60	5.52	5.95	0.9	0.65
Largest, lb	16.5	15.2	12.3	14.7	14.2	15.1	1.4	0.18
Time spent eating								
Total, min./day	806	823	849	821	808	796	52.7	0.98
Avg. meal, min.	180	166	154	160	153	172	20.4	0.91
Water intake, L/day	28.6	28.0	26.5	27.2	30.7	29.6	2.6	0.65

[1]CON= no added Rumensin or dietary buffer, LOWBUF= 0.75% DM Acid Buf, HIBUF= 1.25% DM Acid Buf, BICARB= 1.25% DM sodium bicarbonate, RUM= 28 grams/ton Rumensin, RUM+BUF= 28 grams/ton Rumensin and 0.75% DM Acid Buf.
[abcde]Means in a row with unlike superscripts differ ($P < 0.10$).

Differences in water intake between dietary treatments were not observed (Table 3). This may indicate that cattle experiencing acidosis do not consume water differently, or that animals in our experiment were not experiencing enough acidosis to cause changes in water intake patterns.

VFA Analysis

Analyses of volatile fatty acids yielded similar results among dietary treatments. Total VFA was not different across treatments, averaging 105 m*M* (data not shown). Individual VFA was not influenced by diet treatment, suggesting little effect of buffer on VFA composition being produced in the rumen. Surprisingly, Rumensin did not decrease the acetate:proprionate (A:P) ratio as expected. As a general rule, feeding Rumensin will increase propionate production resulting in A:P ratios of 1.6 to 2.0. In previous experiments evaluating Rumensin, the control-type diets containing no Rumensin would have A:P ratios in the range of 2.0 to 2.4. It appears that CON fed cattle did not respond in this experiment. The periods in this experiment were 14 days, with only 9 days of adaptation. Our design did not include inoculation of cattle with rumen fluid from cattle fed no Rumensin or buffer. Both of these issues may have had an impact on the heifers fed CON in this experiment. The concern is any carryover effect of either Rumensin or buffers when heifers are switched to CON diet, particularly for VFA production data which is dependent on the microbial population. These populations are dynamic and 9 days of adaptation should be adequate, but this may have been an issue given the data for heifers when fed CON.

Because no interactions were observed between dietary treatment and time of day, main effect of time data are illustrated in Figure 1. Heifers were fed once daily at 0800 hour. As expected, total VFA production increased during the day with peak production between 5.5 and 8.5 hours post feeding. Composition as well as amount produced changed over time. Molar percentages

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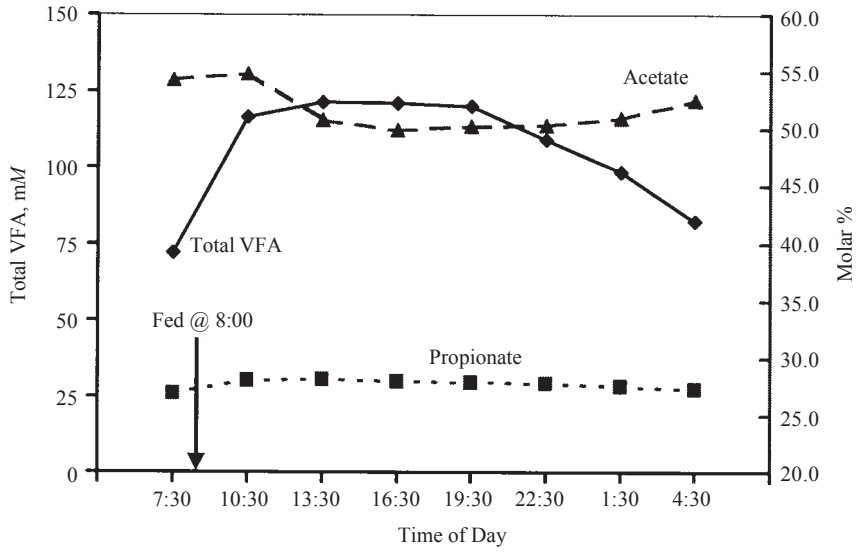

Figure 1. Schematic representing change over time across all treatments for total VFA concentration (m*M*) and molar percentages of acetate and propionate. Heifers were fed at 8:00 daily.

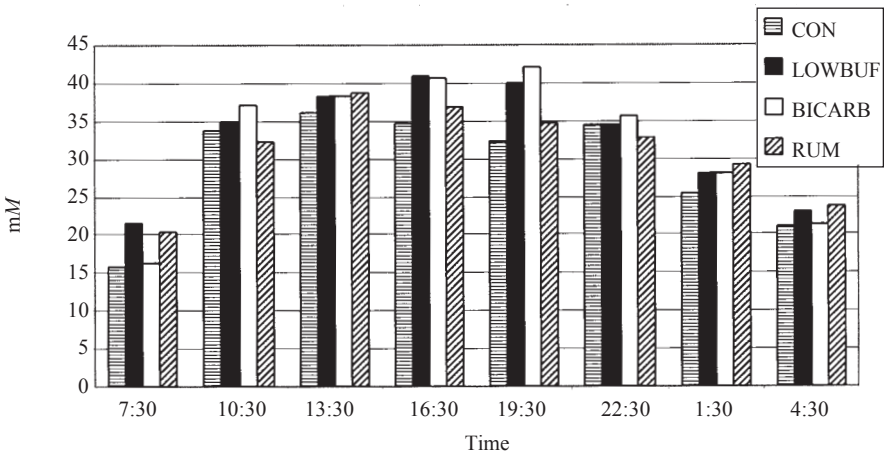

Figure 2. Propionate concentration (m*M*) for CON= no added Rumensin or dietary buffer, LOWBUF= 0.75% DM Acid Buf, BICARB= 1.25% DM sodium bicarbonate, and RUM= 28 grams/ton Rumensin across time of day. Time of feeding was 8:00.

of acetate were highest (54.3%) before feeding (measured at 0730 hour) and lowest 8.5 hours post feeding at 49.9% of total VFA. Propionate production responded similar to total VFA; however, molar percentage was the inverse of acetate with highest percentages 5.5 to 8.5 hours post feeding (30.6%) and lowest prior to feeding at 0730 hour. Figure 1 demonstrates the change in total VFA (m*M* concentration) and molar percentages of acetate and propionate over time of day. Presumably, total VFA and propionate responses indicate that starch utilization is greatest at 5.5 to 8.5 hours following feeding, which would be expected. Then, less substrate and certainly less starch are available over the night and early morning as indicated by total VFA and acetate. During this time, rumen pH increases, total VFA decreases and acetate increases as a percentage of total VFA. Because of these changes in acetate and propionate production, the A:P ratio is lowest 5.5 to 8.5 hours post feeding at 1.78 and highest just prior to feeding at 2.24. However, feeding Rumensin or Acid Buf increased propionate prior to feeding, during times of high A:P ratios (Figure 2).

In summary, feeding Acid Buf and bicarbonate increased rumen pH when heifers were fed a finishing diet containing an 80:20 mixture of high-moisture corn:dry rolled corn. However, DMI was decreased by feeding Acid Buf. Therefore, the higher pH observed with heifers fed Acid Buf may be due to lower DMI, or presumably a combination of buffering and lower intakes. Based on rumen fluid samples over a 24-hour period, it is unclear whether Acid Buf will result in similar performance in production situations. Given the positive attributes of Rumensin in mediating DMI in the feedlot, lower intakes or intake control may be a benefit of feeding Acid Buf if gain is maintained. As for level of Acid Buf, there appeared to be little change between the 0.75 (LOWBUF) and 1.25 % (HIBUF) Acid Buf treatments, except for intake. With the observed DMI in this experiment, feeding LOWBUF resulted in 72.1 grams per day consumption of Acid Buf; whereas the HIBUF led to 113.4 grams per day of consumption. Further evaluation of Acid Buf with concentrations up to 0.75% in production settings would be beneficial.

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