Short communication: Effect of calf starter on rumen pH of Holstein dairy calves at weaning

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ABSTRACT

The objective of this study was to evaluate the effect of feeding calf starter on rumen pH of dairy calves during weaning transition. Twenty Holstein bull calves were paired into 10 blocks by starting date of the study and body weight, and fed either milk replacer and hay (MR) or MR, hay, and a commercial texturized calf starter (MR+S) in a randomized complete block design. All calves were fed 750 g/d of milk replacer as the basal diet. Calves on MR+S treatment were also fed a calf starter ad libitum to maintain similar energy intake between calves within blocks, and MR calves were fed additional milk replacer that was equivalent to energy from calf starter intake. When MR+S calves consumed a calf starter at 680 g/d for 3 consecutive d, rumen pH of a MR+S calf and his MR counterpart was measured continuously for 3 d using a small ruminant rumen pH measurement system. Treatment did not affect minimum pH, mean pH, maximum pH, standard deviation of mean pH, and duration or area under pH 5.8, indicating that calf starter consumption did not appear to affect rumen pH. However, hay intake was negatively correlated to area under pH 5.8, with a breakpoint at 0.080 kg/d intake, suggesting hay intake might play an important role in mitigating ruminal acidosis in dairy calves during weaning transition.

Key words: dairy calf, weaning transition, rumen pH

Short Communication

To foster rumen development, it is recommended that calves maximize intake of calf starter, which is readily fermented in the rumen, before weaning (NRC, 2001). However, rapid ruminal fermentation lowers rumen pH if proton production outweighs proton removal. While low rumen pH has been associated with detrimental health effects in mature ruminants (Nocek, 1997), fermentation of calf starter in the rumen will promote papillae development (Stobo et al., 1966) because of en-

hanced production of butyrate and propionate (Sander et al., 1959). In the literature, rumen pH of dairy calves is lower than that in mature cows. When calves were fed diets containing 40 to 100% concentrate, the average rumen pH ranged from 5.09 to 5.31 (Suárez et al., 2007) and rumen pH appeared to increase with age between 35 and 70 d (Khan et al., 2008). However, regulatory mechanisms of rumen pH in dairy calves have not been extensively studied. Previous studies evaluating rumen pH in calves did not measure pH continuously, but at one time point between 1 and 5 h post-feeding (Khan et al., 2007; Suárez et al., 2007); as such, the pH data did not account for diurnal variation and did not determine the duration or severity of rumen acidosis. In studies using lactating cows, continuous rumen pH measurements have recently become a common approach to evaluate effects of dietary treatments on rumen fermentation (Krause and Oetzel, 2006; AlZahal et al., 2007; Penner et al., 2009b). Continuous rumen pH measurements often allow the detection of differences in duration and severity of SARA even when mean pH is not significantly different (Yang et al., 2001). The objective of the present study was to investigate the effects of feeding calf starter on rumen pH at weaning by continuous rumen pH measurements. We hypothesized that consumption of calf starter would decrease rumen pH.

All procedures for the animal study were approved by the Animal Care and Use Committee for Livestock at the University of Alberta, using the guidelines of the Canadian Council for Animal Care (Ottawa, ON, Canada). Twenty Holstein bull calves (46.7 ± 1.0 kg of BW and 13.1 ± 0.4 d of age) were obtained from a commercial dairy farm in October 2008 ($n = 10$) and May 2009 ($n = 10$). Prior to arrival, calves were individually housed and were fed up to 4 L/d of pasteurized whole milk but had no access to calf starter. After calves were moved to the Metabolic Unit at the University of Alberta Edmonton Research Station, all animals were housed in 3.05×3.66 m individual pens with wood shavings for bedding. All animals had ad libitum access to water and chopped hay throughout the study. Calves obtained in October 2008 were fed chopped timothy hay (7.7% CP, 65.6% NDF), whereas calves obtained in

Received February 15, 2011.

Accepted August 1, 2011.

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May 2009 were fed chopped mixed legume hay (15.0% CP, 56.8% NDF). Twenty calves were paired into 10 blocks using the starting date of the study and BW as blocking criteria. For each block, one calf was assigned to milk replacer (**MR**) treatment, and the other calf in the same block was assigned to MR and starter (**MR+S**) treatment.

All calves were bottle-fed milk replacer (22% CP, 17% fat, and 45% lactose; high-performance milk replacer; Grober Nutrition, Cambridge, ON, Canada) at 750 g/d (12.5% wt/vol). The MR+S calves were offered a commercial texturized calf starter containing canola meal, soybean meal, wheat, barley, corn, peas, and vitamins and minerals with 23% CP and 4% ether extract (**EE**) as the guaranteed minimum (19.5% NDF, 27.1% starch; Wetaskiwin Co-Op Country Junction, Wetaskiwin, AB, Canada) ad libitum. Using these values, the ME values of the milk replacer and starter, respectively, were calculated using the NRC (2001) formulas below:

$$\text{Milk replacer: ME} = 0.93 \times (0.057 \times \% \text{CP} + 0.092 \times \% \text{fat} + 0.0395 \times \% \text{lactose}),$$

$$\text{Calf starter: ME} = [(1.01 \times \text{DE}) - 0.45] + [0.0046 \times (\% \text{EE} - 3)]$$

$$\text{Digestible energy (DE)} = 0.7 \times [(0.057 \times \% \text{CP}) + (0.092 \times \% \text{EE}) + (0.0415 \times \% \text{carbohydrates})],$$

$$\text{Carbohydrate content} = 100 - \text{EE} - \text{CP} - \text{ash}.$$

For the MR+S calves, starter intake was recorded daily, and ME intake from starter was calculated. The MR calves were fed additional milk replacer that supplied ME that was equivalent to ME intake from calf starter of their counterpart MR+S calves within the same block. Therefore, calves within each block were expected to have similar ME intake, which attenuates the confounding effect of energy intake within blocks. Milk replacer was offered twice daily in 2 equal portions at 0515 and 1515 h, and starter was offered once daily at 0515 h. When a calf on MR+S treatment consumed starter at 680 g/d for 3 consecutive d, a small ruminant ruminal pH measurement system (**SRS**; Dascor Inc., Escondido, CA) with a diameter of 20.6 mm, 138-mm length, and 245-g weight, was given as a bolus to both calves within a block; calves were placed in a reclining position during bolus application, to ensure that the SRS entered the rumen dorsally and was not caught in the reticulum. The SRS was calibrated before and after

the rumen pH measurement periods as described by Penner et al. (2009a). Rumen pH was measured every 2 min continuously for 3 d and hay intake was measured daily. After the rumen pH measurement period, both calves within the same block were killed at 1100 and 1200 h by stunning by captive bolt followed by exsanguination, at which time the SRS was retrieved from the rumen. The sequence of harvest was alternated by treatment at each time.

Data were analyzed as a randomized complete block design using PROC MIXED of SAS (v. 9.1; SAS Institute Inc., Cary, NC). The statistical model used was

$$Y_{ij} = \mu + B_i + T_j + e_{ij},$$

where Y_{ij} is the dependent variable, μ is the overall mean, B_i is the effect of block ($i = 1$ to 10), T_j is the effect of treatment ($j = 1$ to 2), and e_{ij} is the residual errors. Data were expressed as least squares means $\pm$ standard error, and significance was declared at $P < 0.05$ and a tendency of treatment effects was declared at $P < 0.10$. To determine correlations between hay intake and rumen pH, PROC CORR was used, followed by PROC NLIN to perform breakpoint analysis. Due to a recurring respiratory illness, 1 block of animals was removed from the trial and was not included in statistical analysis. In addition, rumen pH data from 4 calves were not included due to SRS failures.

Contrary to our hypothesis, minimum, mean, maximum pH, SD of pH, and duration and area under pH 5.8 were not affected by treatment (Table 1). Although hay intake did not differ between MR+S and MR calves during the rumen pH measurement period, hay intake was negatively correlated to the area under pH 5.8 ($r = -0.78$; $P < 0.01$; Figure 1). Because of the significant correlation between hay intake and area under pH 5.8, pH data were also analyzed using hay intake as a covariate, and we found that area under pH 5.8 was lower for the MR+S compared with MR calves (0.70 vs. 5.38 pH $\times$ min/d; $P < 0.05$), but the other pH response variables were not affected. These data suggested that consumption of a calf starter is not likely the primary factor increasing the severity of SARA in dairy calves at weaning.

It is possible that MR+S calves had greater capacity to absorb fermentation acids to maintain rumen pH, as fermentation is important in the development of ruminal epithelia (Sander et al., 1959). It is also possible that milk replacer leaked from the esophageal groove fermented in the rumen, decreasing rumen pH of MR calves. However, in calves fed whole milk at 10% BW through nipple pails, leakage from the esophageal groove occurred only 2.2% of the time, and then only in

Table 1. Rumen pH profile of Holstein bull calves fed calf milk replacer and hay only (MR) or milk replacer and hay and calf starter ad libitum (MR+S)

Item	MR	MR+S	P-value
Feed parameter			
Starter DMI, g/d	N/A	759 ± 44	N/A
Milk replacer DMI, g/d	1,443 ± 46	750	N/A
Hay DMI, g/d	229 ± 66	344 ± 76	0.13
Forage NDF intake, g/d	135 ± 38	205 ± 43	0.12
NDF intake, g/d	135 ± 37	324 ± 43	<0.01
Starch intake, g/d	6 ± 2	174 ± 23	<0.01
pH			
Minimum pH	5.35 ± 0.20	5.47 ± 0.25	0.63
Mean pH	6.42 ± 0.10	6.27 ± 0.12	0.32
Maximum pH	7.02 ± 0.09	7.17 ± 0.11	0.64
SD pH	0.31 ± 0.05	0.26 ± 0.07	0.53
Duration pH <5.8, min/d	101 ± 100	237 ± 126	0.44
Area pH <5.8, pH × min/d	49.3 ± 36.5	64.2 ± 47.4	0.82

quantities less than 5 mL (Wise and Anderson, 1939). As such, similar rumen pH between MR and MR+S calves was not likely attributed to fermentation of milk replacer leaked from the esophageal groove, but the possibility cannot be excluded.

Previously, average rumen pH has been measured between 5.09 and 5.31 in calves fed various proportions of concentrate in the diet (Suárez et al., 2007), and 5.19 to 6.16 when different starch sources in the calf starter were provided (Khan et al., 2008), which is lower than our results. Values from these studies represent the average individual measurement taken from several animals, taken between 1 and 5 h post-feeding, so must be interpreted with caution. During the first

5 h post-feeding, rumen pH is depressed to a greater extent relative to the rest of the day, so measurements taken during this time frame only would provide biased rumen pH data. Based on our results, it appears that calf daily average rumen pH may not be lower than in mature cows, although variability in mean pH is higher in calves than in mature cows (Penner and Oba, 2009; Yang and Beauchemin, 2006). The increased variability in mean rumen pH suggests animal-to-animal variation is even larger in growing calves than it is in mature cows, irrespective of dietary treatment, suggesting other factors may also be important in regulating rumen pH.

In the current data set, hay intake negatively correlated to the severity of SARA (area under pH 5.8) with a breakpoint of 0.080 kg/d, suggesting that hay consumption, even at small amounts, may contribute to mitigating SARA. Long-particle forage, such as hay, stimulates chewing, which promotes salivary buffer flow into the rumen. In mature dairy cows, salivary buffer flow is estimated to neutralize 30% of all protons produced in the rumen (Allen, 1997), so changes in salivary buffer flow rate caused by variable hay consumption may affect rumen pH. In lactating dairy cows, dietary forage NDF inclusion is positively correlated to mean rumen pH (Allen, 1997), and our results suggest that this may hold true for dairy calves during weaning transition.

In conclusion, calf starter consumption may not be the primary factor affecting rumen pH of dairy calves at weaning, and the role of hay intake in regulation of rumen pH of dairy calves warrants further investigation.

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Figure 1. Relationship between hay DMI and area under pH 5.8. Calves were fed either a diet of milk replacer and hay or a diet of milk replacer, calf starter, and hay. Rumen pH was measured for 3 d after a calf consumed 680 g of calf starter/d for 3 consecutive days. Hay DMI was negatively correlated to area under pH 5.8 ($r = -0.78$; $P < 0.01$). The breakpoint analysis showed that area under pH 5.8 becomes zero at hay DMI of 0.080 kg/d.

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