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Increased feeding frequency increased milk fat yield and may reduce the severity of subacute ruminal acidosis in higher-risk cows

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ABSTRACT

The objectives of this study were to determine whether feeding behavior is different between cows at higher or lower risk for subacute ruminal acidosis (SARA) and whether increasing feeding frequency could be used to reduce the severity of SARA in higher-risk cows. In preliminary studies, 16 ruminally cannulated lactating cows were fed high-grain diets once per day to increase the risk of SARA. After a 17-d diet adaptation, ruminal pH was measured every 30 s over 24 h. Cows were classified as higher-risk ($n = 7$) or lower-risk ($n = 9$) for SARA based on an acidosis index (area of $\text{pH} < 5.8/\text{dry matter intake}$). Feeding behavior was recorded every 5 min over the same 24 h. The 24-h observation period was analyzed in 3 periods of 8 h after feeding. Although there was no significant difference in overall dry matter intake, higher-risk cows spent more time eating in the first 8-h period after feeding than lower-risk cows (186 vs. 153 min) and less time eating in the third 8-h period (19 vs. 43 min). In the primary experiment, 8 ruminally cannulated lactating cows were fed a high-grain diet once per day ($1\times$; 0800 h) or 3 times per day ($3\times$; 0800, 1500, and 2000 h) in a crossover design with 21-d periods (16 d of treatment adaptation and 5 d of data collection). Rumen pH and feeding behavior were measured over 72 h. Behavior data were summarized separately for the 3 periods (0800 to 1500, 1500 to 2200, and 2200 to 0800 h). Four cows were categorized as higher-risk and 4 as lower-risk, based on their acidosis index. The $3\times$ feeding reduced eating time between 0800 and 1500 h (99 vs. 145 min) and increased eating time between 2200 and 0800 h (76 vs. 43 min) for all cows, regardless of category, compared with $1\times$ feeding. For higher-risk cows, $3\times$ feeding reduced the area below $\text{pH} 5.8$ (51 vs. 98 $\text{pH} \times \text{min}/\text{d}$), but it did not affect rumen pH for the lower-risk cows. Milk yield was not different between groups, but $3\times$ feeding increased milk fat yield (1.22 vs. 1.08 kg/d) for all cows, regardless of category, compared to $1\times$ feeding. Our results sug-

gest that cows at higher risk for SARA eat less evenly throughout the day; increasing feeding frequency may reduce the severity of SARA in higher-risk cows and may also increase milk fat yield.

Key words: subacute ruminal acidosis, feeding frequency, feeding behavior, milk fat

INTRODUCTION

Subacute ruminal acidosis is a metabolic disorder found mainly in high-producing dairy cows that are fed highly fermentable diets. A prolonged rumen pH below 5.8 can lead to problems in animal health (such as laminitis and liver abscess) and production losses from milk fat depression and reduced DMI (Nocek, 1997). Previous research has established that individual rumen pH response to the same high-grain diet in beef steers (Schlau et al., 2012) and dairy cows (Penner et al., 2007) varies widely, but the causes of this variation have not been clearly identified. In recent studies, cows were categorized as tolerant of or susceptible to a high-grain diet using an acidosis index, which is the severity of SARA normalized for intake (area below $\text{pH} 5.8/\text{DMI}$; Penner et al., 2009), and efforts were made to characterize animals that were tolerant of a high-grain diet. Schlau et al. (2012) observed decreased VFA concentrations in tolerant animals, possibly due to decreased VFA production or increased absorption. Gao and Oba (2014) reported that tolerant animals showed less sorting against long particles. However, the distribution of feeding behavior among animals with different tolerance to a high-grain diet has not yet been evaluated. Eating larger amounts of feed over a short period can lead to a rapid decrease in rumen pH (González et al., 2012), so it is possible that cows more prone to SARA exhibit different feeding behaviors or eating patterns throughout the day.

Previous studies have found that increasing feeding frequency reduced diurnal variation in rumen pH (French and Kennelly 1990; Shabi et al., 1999). The delivery of fresh feed stimulated eating in cows (DeVries and von Keyserlingk, 2005) and feeding more often led to more frequent peaks in eating activity, correspond-

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ing to feeding times (Mäntysaari et al., 2006). DeVries et al. (2005) also found that feeding 4 times per day, instead of once or twice, reduced the time spent eating in the 90 min after each feeding. Therefore, increasing the frequency of feeding may encourage distribution of eating throughout the day, reducing large intake after feed delivery and contributing to a more stable pH. Although the effects of feeding frequency have been extensively studied, findings for its effect on rumen pH have not been consistent (French and Kennelly, 1990; Robinson and McQueen, 1994; Shabi et al., 1999).

The objective of the preliminary studies was to determine whether cows that differed in their risk for SARA also differed in their distribution of feeding behavior throughout the day. We hypothesized that higher-risk cows fed once per day would eat for a longer period of time soon after feeding and would reduce eating time later in the day. The objective of the primary experiment was to determine the effects of increased feeding frequency on feeding behavior and rumen pH in lactating dairy cows with different risk levels for developing SARA. We hypothesized that frequent feeding would increase the distribution of eating throughout the day and reduce the severity of SARA in higher-risk cows.

MATERIALS AND METHODS

All experimental procedures used in this study were approved by the University of Alberta Animal Care Committee and conducted according to the guidelines of the Canadian Council of Animal Care (CCAC, 2009). All cows were housed individually in a tiestall barn bedded with wood shavings and with free access to water. Cows were milked twice per day at 0400 and 1500 h. Cows were fed for 5 to 10% daily orts.

Preliminary Studies

Study 1 was conducted in 2012 (Gao and Oba, 2014) with 10 ruminally cannulated lactating Holstein cows (DIM = 277 ± 37 ; BW = 600 ± 77 kg), and study 2 was conducted in 2014 (Gao and Oba, 2015) with 9 ruminally cannulated lactating Holstein cows (DIM = 247 ± 19 ; BW = 686 ± 42 kg). In both studies, cows were fed high-grain diets once per day to induce SARA (Table 1), at 0800 h for study 1 and 0900 h for study 2. For both studies, cows were fed ad libitum for 21 d with 17 d of diet adaptation and 4 d of sample and data collection. Although the preliminary studies focused solely on the collection of rumen pH and behavior data, Gao and Oba (2014) also measured VFA concentrations from rumen fluid samples; sorting behavior; blood metabolites; and milk yield and components. For cows used in both studies ($n = 3$), data from study 2 were

used, leaving a total of 16 cows for statistical analysis. Of these, 3 were primiparous and 13 were multiparous.

In both studies, rumen fluid pH was measured continuously in the ventral sac every 30 s for 24 h on d 18 using the pH measurement system evaluated by Penner et al. (2006). This system was used to determine mean, minimum, and maximum pH, as well as duration and area below pH of 5.8 for each cow. The data were then used to determine an acidosis index (area below pH 5.8/DMI; Penner et al., 2009), which indicated the severity of SARA normalized for intake. Cows below the acidosis index threshold of 1.0 were categorized as lower-risk, and cows above the threshold were categorized as higher-risk.

For both studies, we recorded feeding behavior over 24 h on d 18, coinciding with rumen pH recording. All behavior observers were trained to standardize behavior definitions and recordings. Cows were observed for eating and ruminating every 5 min, and the behavior performed at that time was recorded and assumed to last for the full 5 min (Beauchemin et al., 2003). We summarized feeding behavior for 3 time periods of 8 h relative to feeding, to account for the different feeding times in the 2 experiments (e.g., if the cow was fed at 0800 h, time period 1 was 0800 to 1600 h, time period 2 was 1600 to 2400 h, and time period 3 was 2400 to 0800 h). This approach allowed us to determine when the cows spent more time eating, relative to feed delivery. The minimum interval between bouts of eating was ≥ 10 min, or else cows were assumed to be still eating, as described by Dado and Allen (1993).

We evaluated all response variables using the Fit Model procedure in JMP (version 11, SAS Institute Inc., Cary, NC). The model included the fixed effects of experiment (1a vs. 1b), category (higher risk vs. lower risk of SARA), and the interaction of experiment by category. Because the interaction between experiment and category was not significant ($P > 0.10$), the interaction term was removed from the statistical model. We declared significance at $P \leq 0.05$ and tendency at $0.05 < P \leq 0.10$.

Primary Experiment

Eight ruminally cannulated lactating Holstein cows were used in this crossover design study with periods of 21 d (Table 2). Treatments were feeding frequency: 4 cows were fed once per day ($1\times$) at 0800 h, and the other 4 cows were fed 3 times per day ($3\times$) at 0800, 1500, and 2200 h. We chose 3 feedings because a previous study had found increased treatment effects on feeding behavior when feeding frequency was more than twice per day (DeVries et al., 2005). A TMR was mixed once before the 0800 h feeding for all cows; the

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