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Association of rumination time and health status with milk yield and composition in early-lactation dairy cows

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ABSTRACT

The objective of this study was to determine the associations of rumination time (RT) and health status with milk yield and milk composition. This study used 339 dairy cows from 4 commercial dairy farms in Ontario, Canada (first lactation, n = 107; second lactation, n = 112; ≥third lactation, n = 120). Rumination time was monitored (24 h/d) using an automated system from 1 to 28 d in milk (DIM). Cows were milked 3×/d on each farm, and 2 farms recorded milk weights at each milking to determine daily milk yield (n = 170). Cows were also monitored for milk composition (fat and protein content) 1×/wk. Last, subclinical ketosis (SCK) was diagnosed 1×/wk; cows with at least one blood sample with β-hydroxybutyrate ≥1.2 mmol/L postcalving were diagnosed with SCK. Cases of retained placenta, metritis, milk fever, or mastitis during the study period were also recorded. Cows were categorized into 1 of 4 groups: healthy cows that had no SCK or any other health issue (HLT; n = 139); cows that were treated for at least one health issue other than SCK (HLT+; n = 50); SCK cows with no other health problems during transition (HYK; n = 97); or cows that had SCK and one or more other health problems (HYK+; n = 53). All data were summarized by week across cows, and the associations between rumination time and milk yield (n = 170) and milk composition (n = 339) were modeled. Across all lactations, and including all health categories, milk yield increased by week, whereas fat and protein content both decreased by week. A positive association was found between summarized RT and milk yield in first-lactation (+0.006 ± 0.003 kg/min of RT) and second-lactation (+0.015 ± 0.004 kg/min of RT) cows from 4 to 28 DIM, as well as in ≥third-lactation cows; however, the relationship between RT and milk yield differed across weeks in those cows. A negative association between RT and milk fat content was found in ≥third-lactation cows (−0.002 ± 0.00059 percentage points/min of RT). From 4 to 28 DIM, ≥third-lactation HYK and HYK+ cows produced less protein (0.11 ± 0.051 and 0.13 ± 0.056 percentage points, respectively) than HLT cows. Over the 4-wk observation period, first-lactation HYK+ cows tended to deposit 0.11 ± 0.056 percentage points less protein in their milk compared with HLT cows. Second-lactation HYK+ cows produced less milk than HLT cows each week during early lactation. In summary, RT was positively associated with milk yield in early-lactation dairy cows, across all lactations, and negatively associated with milk fat content in ≥third-lactation cows. Further, the results showed that early-lactation cows that experience SCK, particularly with one or more other health problems, might have decreased milk yield and milk protein content.

Key words: early lactation, rumination, behavior, ketosis

INTRODUCTION

Dairy cows are a foregut fermenting species and thus, rumination is a natural behavior. A proper ration should include adequate physically effective fiber (Kononoff et al., 2003a; Beauchemin and Yang, 2005) to stimulate regurgitation, remastication, and swallowing of boluses (Welch, 1982). The process of rumination increases the surface area of feed particles, making them more accessible to microbes, but it also stimulates saliva production to help buffer the rumen and create a homeostatic environment for microbes (Erdman, 1988; Allen, 1997). Rumination facilitates the passage of DM from the rumen through the gastrointestinal tract as particles are broken down. As passage rate increases, DMI increases in dairy cows (Nelson and Satter, 1992). Thus, based on the role that rumination plays in digestion and passage rate, it would be expected that rumination activity be related to feed intake in dairy cows (Clément et al., 2014).

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To date, rumination activity has been most consistently associated with intake of physically effective NDF (**peNDF**), which combines dietary particle length and dietary NDF content, and is directly related to chewing activity and rumination (Yang and Beauchemin, 2006a). As the level of peNDF increases in the diet, the cow is stimulated to ruminate more (Zebeli et al., 2012). There is less consistent association of rumination with overall DMI in dairy cows. Schirmann et al. (2012) found that cows spend more time ruminating about 4 h after periods of high feed intake but found no association across the day. Rumination time has, more recently, been found to be a significant but small contributor in a DMI prediction model (Clément et al., 2014).

Given that DMI is the primary driver of milk production (Bargo et al., 2002), rumination time (**RT**) may be relatable to milk yield and milk composition. In fact, Soriani et al. (2013) were able to identify a positive association between milk yield and RT. Further, rumination behavior could be a promising indicator to track metabolic conditions associated with a decrease in DMI (Soriani et al., 2012), such as subclinical ketosis (**SCK**). This metabolic condition is defined as an elevation of ketone bodies in the blood, specifically BHB concentration $\geq$1.2 mmol/L during the postcalving period, with the highest incidence occurring between 5 and 16 DIM (Geishauser et al., 1998; Oetzel, 2004; McArt et al., 2012). To generate energy, fatty acids are converted into ketone bodies and, as these metabolites accumulate in circulation, DMI further decreases, as ketone bodies increase satiety (Allen et al., 2009; Piantoni and Allen, 2015). Kaufman et al. (2016) recently demonstrated that cows diagnosed with SCK after calving ruminate less than healthy cows during the week before and the week after calving. While fatty acids are being mobilized, they may also be incorporated into milk fat (Van Haelst et al., 2008); therefore, it may be possible to use milk composition, specifically fat content of the milk, as a diagnostic tool for SCK. Other researchers have found that negative energy balance tends to increase milk fat content while decreasing milk protein content (Miettinen and Setälä, 1993; Nir Markusfeld, 2003). Related to that, increased milk fat:protein (**FP**) ratios are associated with negative energy balance and may be indicative of SCK (Grieve et al., 1986; Duffield et al., 1997; Jenkins et al., 2015).

The objective of this study was to determine associations of RT and health status (SCK) with milk yield and milk composition. We hypothesized that greater RT would be associated with greater milk yield. We also predicted that SCK would be associated with lower milk yield and higher milk fat due to an increase in circulating fatty acids during fat mobilization.

MATERIALS AND METHODS

This research was part of a larger study aimed at evaluating the efficacy of rumination monitoring for the early detection of SCK. As such, detailed descriptions of the methodology are presented in Kaufman et al. (2016). In summary, 339 dairy cows (first lactation, n = 107; second lactation, n = 112; $\geq$third lactation, n = 120) on 4 commercial dairy farms were monitored for daily RT and sampled once weekly for milk component analysis and SCK testing from 4 to 28 DIM. Daily milk yield data were collected on 2 of the 4 farms. All cows were housed in freestall facilities, milked in a parlor 3×/d (farm 1: 0300, 1100, and 1900 h; farm 2: 0500, 1300, and 2100 h; farm 3: 0500, 1300, and 2100 h; farm 4: 0430, 1315, and 2115 h), and fed a TMR 1×/d (farm 1: 0700 h; farm 2: 0630 h; farm 3: 0500 h; farm 4: 0730 h). The nutritional breakdown of each farm's fresh-cow TMR is described in Kaufman et al. (2016). Physically effective NDF was calculated (as per Yang and Beauchemin, 2006a) as (1) the proportion of DM retained by the 19- and 8-mm sieves of the Penn State Particle Separator (PSPS; Kononoff et al., 2003b) multiplied by dietary NDF content ($peNDF_{>8}$); and (2) the proportion of DM retained by 19-, 8-, and 1.18-mm sieves of the PSPS multiplied by dietary NDF content ($peNDF_{>1.18}$). The $peNDF_{>8}$ for the fresh-cow ration on farms 1, 2, 3, and 4 was 19.1, 15.3, 13.0, and 18.6, respectively. The $peNDF_{>1.18}$ for the fresh-cow ration on farms 1, 2, 3, and 4 was 28.5, 25.2, 23.1, and 26.4, respectively. Animal use and study design were approved by the University of Guelph's Animal Care Committee (AUP#2518) and Research Ethics Board (REB#14JA015), respectively.

Rumination Behavior

As described by Kaufman et al. (2016), rumination activity was monitored 24 h/d from 2 wk before calving until 4 wk after calving, using an electronic rumination detection system (Hi-Tag, SCR Engineers Ltd., Netanya, Israel), as validated by Schirmann et al. (2009). Each individual cow's rumination data were uploaded to the system at least once every 23 h. The system recorded how many minutes the cow was ruminating per 2-h interval; the twelve 2-h intervals were summed each day to create a daily RT.

Determining Health Status

Blood samples were collected from the coccygeal vein 1×/wk, and blood BHB concentration was measured in millimoles per liter using the Precision Xtra meter (Abbott Diabetes Care, Saint Laurent, QC, Canada),