# Something to Ruminate on...Why We Should Watch Cows Chew

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## ▪ Take Home Messages

- Rumination is an important behaviour for dairy cows to perform to maintain rumen digestion, health, and efficiency.
- While rumination is primarily influenced by dietary composition, it is also influenced by cow health, environment, stressors, and physiological events.
- Monitoring rumination behaviour may be useful for detection of calving and estrus, as well as the identification of disease and risk for disease.
- While visual detection of changes in rumination is difficult, validated electronic tools are available to automatically record and monitor this behaviour.

## ▪ Introduction

Over the past couple of decades we have seen a significant amount of research on cow behaviour, including using behaviour to evaluate nutrition, housing, and management strategies, as well as the utility of monitoring cow behaviour for the identification and early detection of health challenges. Much of this research has been focused on cow feeding and lying and standing behaviour. More recently we have seen a proliferation of studies focused on rumination behaviour — a behaviour long-known for its critical role in the ruminant digestive process.

This paper will help shed light on findings of such research by describing how monitoring of rumination behaviour may be important for cow management and health. To that end, the importance of dairy cow rumination behaviour will be emphasized. The paper will then describe what factors, both cow and herd level, influence rumination behaviour. Further, empirical evidence will be presented on how dairy cattle alter their rumination activity in response to physiological events and the potential use of rumination behaviour for the identification and early detection of disease. Finally, the paper will describe the need for, and availability of, automated systems for the on-farm monitoring of rumination behaviour.

## ▪ Importance of Rumination Behaviour

As a ruminant species, dairy cows rely on the process of rumination to fully digest their food. Rumination is the process in ruminants whereby there is regurgitation of fibrous digesta from the rumen to the mouth and re-mastication (re-chewing) of that feed (Welch, 1982). The re-chewed feed is ensalivated, formed into a bolus and then swallowed again back to the rumen (Beauchemin, 1991; Welch, 1982). Rumination serves several purposes in the process of digestion. First, this behaviour results in a breakdown of feed into smaller particles, which increases the surface area available (i.e. cell walls) for ruminal microbes to attach and breakdown those food particles into digestion end-products (Welch, 1982). This decreases the amount of time it takes feed to be fermented in the rumen and thus increases the rate of digestion of that feed. In addition to aiding the microbes, reducing feed particle size by rumination also assists in the passage of materials from the rumen. Thus, rumination can potentially impact feed intake levels. For example, if rumination is limited, longer, more fibrous particles will stay in the rumen for a longer duration of time, causing the rumen to feel fuller, potentially limiting dry matter intake (DMI) and reducing milk production. The saliva produced during chewing and bolus formation in rumination not only aids in re-swallowing of that bolus, but also acts to maintain rumen pH (Beauchemin, 1991). The saliva of dairy cows (produced at a rate of 150-200 liters per cow per day) contains a significant amount of bicarbonate, which acts in the rumen as a buffer to decrease acidity levels (Mertens, 1997), which result from the accumulation of volatile fatty acids that are produced as an end-product of microbial fermentation of carbohydrates.

Rumination is stimulated by pressure against the rumen wall from coarse feed material located in the upper part of the rumen (cranial sac and reticulum). In particular, there are receptors that are located within the reticulorumen that sense contact from the fibrous components of the diet (Gordon, 1968), often referred to as the ‘scratch factor’. Thus, the amount of time a cow spends ruminating is dependent on the type and amount of feed consumed. For example, a diet with a high proportion of concentrate will be ruminated less than a diet with a large proportion of forage, particularly if that forage has a long particle length. Thus, for the high-producing dairy cow that consumes considerable amounts of concentrate, it is important that there is an adequate amount of long fibre present in the diet to stimulate rumination and maintain a stable rumen environment. If cows are unable to ruminate for a significant proportion of their day, they risk developing conditions such as sub-acute ruminal acidosis.

Cows typically ruminate for 25–80 min per kg of roughage consumed (Sjaastad et al., 2003). In fact, rumination time has been consistently associated with total dietary neutral detergent fibre (NDF) intake as well as with particle size of the diet. Thus, changes in dietary composition can have significant impacts on the amount of time cows spend ruminating per day. For example, Dado and Allen (1995) demonstrated that rumination time in early lactation dairy cows increased from 380 to 500 min/day when NDF content of the ration was increased from 25 to 35%.

The association of rumination time with total DMI has varied in the literature. Clement et al. (2014) recently found that rumination time was a significant, but small contributor in a DMI prediction model. Schirmann et al. (2012) found a negative correlation between periods of DMI and rumination time in dry cows throughout the day, reflecting the fact that cows cannot feed and ruminate at the same time. Those researchers did find that cows spend more time ruminating about 4 h after periods of high feed intake (Schirmann et al., 2012). This seems to indicate that within-cow variations in rumination data may be used to indicate changes in feeding behaviour and intake, but may not be always consistent in estimating DMI. Alternatively, if we control for much of the variability between cows, we have recently found that rumination can be predictive of both DMI and milk production (Johnston and DeVries, 2015).

While rumination duration is primarily impacted by ration particle size, feed digestibility, and DMI level, it is also an innate behavioural need in cattle. Cows spend a certain amount of time ruminating per day, regardless of the total amount of feed in the rumen (Lindstrom and Redbo, 2000). Further, if this behaviour is limited, cows may become frustrated and exhibit redirected oral behaviours such as tongue rolling.

Rumination typically occurs for 8–9 hours of the day, typically in a diurnal pattern during the time periods when the animal is not active (feeding, milking), but when at rest (lying down). As such, most rumination activity occurs at night, with other major bouts of rumination occurring during the middle of the day in between other periods of activity (DeVries et al., 2009; Figure 2). Rumination typically occurs shortly after bouts of eating have occurred; the time lag between when a cow starts to ruminate and when she stopped eating is inversely proportional to the size of the previous meal; that is, a cow will typically start ruminating much sooner after eating a large meal as compared to a smaller meal. The duration of bouts of rumination will vary from very short (less than 30 min) to long periods of time (multiple hours). The shortest bouts of rumination occur closer to periods of eating, while the longer periods of rumination tend to occur during longer periods of inactivity, i.e. at night (Welch and Hooper, 1988). Given the timing of rumination within the day, a disruption to a cow's normal rest time, due to other factors (for example, increased need to walk, activity related to estrus, calving, social agitation, or other reasons) may result in a decrease in rumination time.

## ■ Factors Influencing Rumination

Daily rumination time has been shown to be highly variable within individual cows (Soriani et al., 2012), but also between herds (Reith and Hoy, 2012). This variation may not only be due to differences in the ration fed; there are other factors that have been shown to influence the amount of time that cows devote to rumination. One consistent finding has been that multiparous cows spend more time (~ 1 h/day) ruminating than primiparous cows (Beauchemin and Rode, 1994; Soriani et al., 2012). While this difference in rumination time may be related to body size and intake level, Beauchemin and Rode (1994) observed that while primiparous and multiparous cows regurgitated a similar number of boluses while ruminating, multiparous cows spent more time chewing each bolus.

Several researchers have shown that physiological events may impact rumination time in cows. For example, rumination time has been shown to reach its nadir at the time of calving (Calamari et al., 2014; Schirmann et al., 2007; Soriani et al., 2012). Schirmann et al. (2007) found that feeding time began to decrease 8 h before calving and rumination time was quick to follow, 4 h before the onset of calving. Those researchers demonstrated that feeding time and rumination time both began to increase at about 4 to 6 h post-calving. This would suggest that within-day monitoring of rumination activity may prove useful for the detection of impending calving events. Similarly, measurement of rumination could also be useful in the detection of estrus. In recent studies, rumination time was reduced, on average by ~20%, on the day before insemination (Pahl et al., 2015) or on the day of estrus (Reith and Hoy, 2012).

Stressful situations cows experience have been demonstrated to cause a reduction in rumination time. In fact, Bristow and Holmes (2007) found that a reduction in rumination time was associated with increased cortisol levels in cattle. Schirmann et al. (2011) studied the effects of social regrouping on dry cows to determine how this related to changes in cow behaviour. Those researchers found that cows that were moved into a new pen, on average, decreased their DMI by 9%, while there was no effect on the DMI of the cows who remained in their home pen. Rumination behaviour of the cows that remained in their home pen decreased from the baseline by ~30 min/day on the day regrouping occurred, however, this value returned to normal the following day. The cows that were moved to a different pen also decreased their rumination by ~30 min/d, but did not return to their baselines levels until 2 days after regrouping.

Similar to the effect of regrouping, overcrowding can influence rumination activity. For examples, Krawczel et al. (2012) demonstrated that increasing free stall and headlock stocking density from 100 to 142% resulted in a drop of rumination time by 0.4 h/day; this change in rumination was associated with more time spent ruminating while standing and less time spent ruminating while lying down. Social hierarchy may also impact rumination activity. Ungerfeld et al. (2014) compared the rumination activity of high and low socially-ranked grazing dairy cows; those researchers found that lower ranked cows ruminated 35% less time than the higher ranked cows. They also found that the lower ranked cows had shorter rumination bouts, which they suggested reflected lower feed intake. Further, in work by Soriani et al. (2012), where it was shown that primiparous cows had a slower increase in rumination post-calving, the researchers suggested that primiparous cows suffer more from the stress of environmental changes at the initiation of lactation than multiparous cows. Overall, these effects of social environment on rumination time indicate the importance of monitoring differences in rumination activity within groups of cows, particularly mixed parity groups, where factors such as competition for resources may have differential effects on cows within the pen.

It has also been shown that environmental stress may impact rumination time. Specifically, cows that are heat stressed showed decreased rumination activity. Soriani et al. (2013) demonstrated a negative relationship between daily maximum temperature-humidity index (THI) and rumination time; they observed a 2.2 min reduction in rumination time for every daily maximum THI unit over a THI of 76. These researchers also found rumination time occurring at night to increase with greater THI. These results are similar to that reported by Moallem et al. (2010) who reported that the primary negative effect of high THI was reduction in rumination time, which subsequently led to a decline in DMI followed by reduced milk production. Soriani et al. (2013) also found that the drop in DMI that occurs as a result of elevated THI was seen in the days following the drop in rumination time. This would suggest that decreased rumination in heat stressed cows is not only an indication of lower intake, but a reduction in the performance of this behaviour may be done by cows pre-emptively in an effort to reduce heat production.

## ▪ Using Rumination to Identify Health Events

In addition to being useful in the identification of physiological events in the life of a cow, as well as stressful situations, rumination monitoring may also be useful in the identification of illness or risk for illness in dairy cows. Several researchers have shown that a decrease in rumination may be a good indicator of discomfort in cows who are experiencing cases of induced mastitis. For example, Siivonen et al. (2011) found that rumination decreased during the 4 to 8 h after experimentally inducing mastitis with an endotoxin. Fitzpatrick et al. (2013) similarly demonstrated decreases in rumination during the first 8 h after an endotoxin challenge (Figure 1). Cows in both of these studies compensated for the decrease in rumination later in the day, such that no differences existed in total daily rumination time. Regardless, the results of these studies suggest that within-day deviations in rumination activity, from typical rumination patterns, may be useful for identifying cows experiencing acute pain, associated with things such as a clinical case of mastitis.

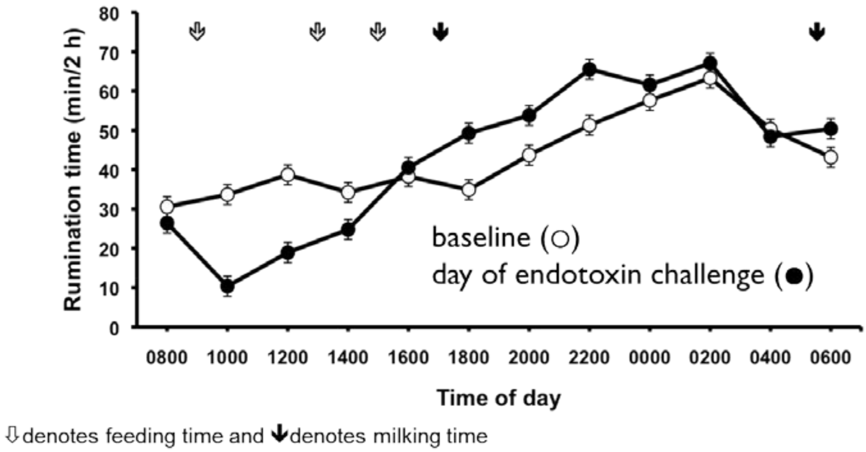


**Figure 1. Rumination time of cows on the day of endotoxin challenge (●) as compared with baseline data (○). Infusion of endotoxin was performed following morning milking (0700 h) on the challenge day (adapted from Fitzpatrick et al., 2013).**

Another potential use for the monitoring of rumination activity is for the identification of metabolic disorders in dairy cows, including ruminal acidosis. Traditional wisdom would suggest that a dairy herd has healthy rumen function when at least 40% of the cows are ruminating at any given time. In previous work we provided experimental evidence supporting this guideline; in a group of healthy cows, on average, 40% were ruminating at those times of the day when rumination behaviour was expected (Figure 2a; DeVries et al., 2009). Alternatively, we found that 10% fewer cows were ruminating during these peak rumination times when a bout of ruminal acidosis was occurring across all cows (Figure 2b). We would not be able to detect suboptimal rumen function (i.e. a herd-level ruminal acidosis event) using this criterion if only a single observation of a herd was undertaken. Rather, to detect a herd-level ruminal acidosis event, greater than 48 individual observations would be required to accurately estimate the percentage of cows ruminating within a herd (DeVries et al., 2009). Such a task would be onerous if conducted visually; however, new technologies that allow for the objective, repeatable, and automated capture of rumination behaviour make this type of behavioural monitoring feasible. For example, currently, there are neck-mounted

(Schirmann et al., 2009) and ear-tag mounted (Bikker et al., 2014) automated systems that are well validated and commercially-available.

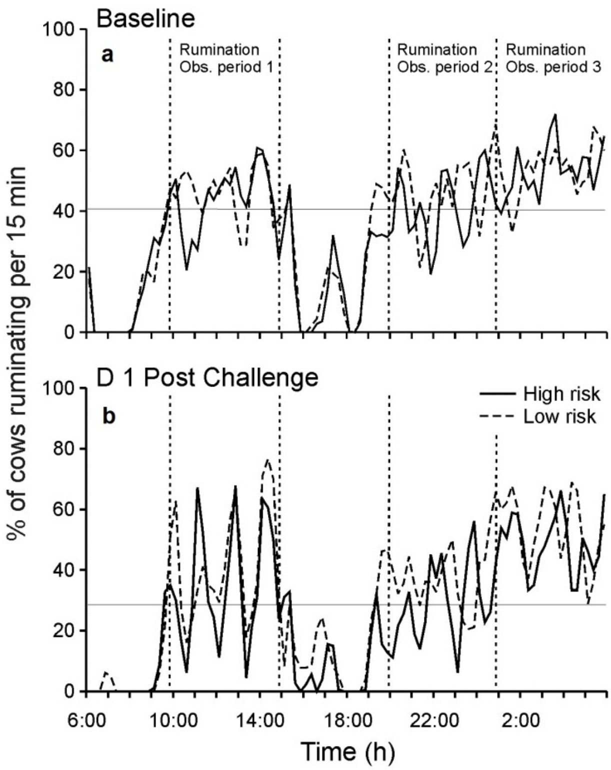


**Figure 2. Percentage of cows ruminating during: (a) a baseline period when cows were healthy and during (b) the 24 h following a ruminal acidosis challenge (d-1 post challenge) for cows at high and low risk for ruminal acidosis (adapted from DeVries et al., 2009).**

Much recent research has focused on the use of rumination behaviour to identify and predict risk of illness in early lactation cows. Soriani et al. (2012) categorized a small sample of cows (n=32) into 3 groups based on rumination time before calving: longer rumination time, middle rumination time and shorter rumination time. Cows in the shorter rumination group not only demonstrated a greater increase of β-hydroxybutyrate after calving, but also a higher incidence of clinical disease (including mastitis, lameness, ketosis and displaced abomasum); these cows also had decreased rumination time after calving. Similarly, Calamari et al. (2014), studying a small group of cows (n=23) reported that cows that were diagnosed with at least one clinical disease postpartum had a lower rumination time in the first week after calving and their increase in rumination time after calving was slower compared with healthy cows. Those researchers also suggested that a slower increase in rumination time post-calving may be associated with systemic inflammation (Calamari et al., 2014). More recently, in a larger study of 339 cows, we observed that cows diagnosed with sub-clinical ketosis after calving showed reduced rumination time, both in the week before calving and the first week after calving, compared to those cows that remained healthy (Kaufman et al., 2015). These differences were accentuated in those cows that not only were diagnosed with subclinical ketosis, but also with one or more other health problems post-partum. Collectively, these studies indicate to us that rumination behaviour may be a promising indicator of metabolic conditions, including the potential to be predictive of the risk of such conditions.

## ■ Conclusions

This proceedings chapter summarizes a number of studies that have been undertaken that collectively provide us with a basic understanding of how rumination behaviour of dairy cows is not only sensitive to dietary composition (particularly effective fibre content and digestibility), but is also altered in response to physiological events, stressors, and health issues. Specifically, events such as calving, illness and pain, and estrus will cause a disruption in rumination. Therefore, monitoring of rumination can provide an accurate indication of a cow’s health, welfare, and physiological status. Visual observation of rumination behaviour is often difficult; thus there is a need to use validated, automated technologies to monitor the rumination behaviour of dairy cows.

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