

# **BIOLOGICAL IMPORTANCE OF RUMINATION AND ITS USE ON-FARM**

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## **INTRODUCTION**

Rumination is controlled by dietary and management factors such as fiber amount and particle size, degree of overcrowding, grouping strategies, and other potential stressors in the management environment. Rumination reflects cow health and is highly sensitive to the state of well-being. However, direct observation of rumination is labor intensive and only a few cows may be monitored intensively at once. In recent years, commercial systems for monitoring rumination activity have become available, and published research indicates that there is reasonable correlation between visual and electronic monitoring systems (Schirmann et al., 2009). Current research and on-farm experiences are beginning to demonstrate the value of monitoring rumination to identify nutritional problems, find cows in estrus, detect health disorders earlier, streamline fresh-cow examinations, and adjust treatment protocols based on cow responsiveness. As research accumulates, we expect routine rumination monitoring to increase because rumination responds to stressors up to 24 h sooner than traditional measurements allowing for more effective cow management.

## **NUTRITIONAL ROLE OF RUMINATION**

Rumination is defined as the regurgitation of fibrous digesta from the rumen to the mouth, remastication and reinsalivation, followed by swallowing and returning of the material to the rumen (Welch, 1982). This cyclical process is influenced by several primary factors including dietary and forage-fiber characteristics, health status, stress, and the cow's management environment (Grant and Albright, 2006; Calamari et al., 2014). Rumination is controlled both by the internal environment of the rumen and the external environment of the cow, i.e. the management environment. We have known for decades that receptors located within the reticulorumen are sensitive to friction or "scratch factor" from the fibrous components of the diet (Gordon, 1968). Rumination facilitates digestion, particle size reduction, and subsequent passage from the rumen thereby influencing dry matter intake. Rumination also stimulates salivary secretion and improves ruminal function via buffering (Beauchemin, 1991).

Rumination is positively related to feeding time and dry matter intake. Following periods of high feed intake, cows spend more time ruminating, usually after a 4-h lag. Restricting feed intake reduces rumination: a 1-kg decrease in dry matter intake has been associated with a 44 min/d reduction in rumination (Metz, 1975).

Cows ruminate 25-80 minutes per kilogram of roughage consumed (Sjaastad et al., 2003). Mertens (1997) reported that mean chewing time was 150 minutes per

kilogram of NDF for long grass hay. This relationship between NDF and chewing response forms the basis of fiber's physical effectiveness in the physically effective NDF (peNDF) feeding system. Physically effective NDF is based on the two fundamental properties of feeds that influence eating and ruminative chewing: fiber content and particle size. However, recent observations of Miner Institute's dairy herd suggest that more than simply the amount and quality of forage-fiber influence daily rumination time (Cotanch, 2015). It may be that cow and nutritional factors set a "normal" maximum amount of rumination activity, and as nutritionists and farm managers we essentially can reduce that maximal activity with non-ideal management.

Ruminant nutritionists have mostly focused on the component of rumination that is determined by fiber physical form and digestibility. However, we know that cows voluntarily control rumination and stop when disturbed. Under acute and chronic stress environments, rumination is depressed: rumination is highly sensitive to cow well-being. Increasingly, the management focus is shifting to these non-nutritional factors that greatly influence rumination.

## RUMINATION AND MANAGEMENT

Figure 1 illustrates several key components of the management environment that may reduce the cow's expected rumination response to dietary peNDF, fiber digestibility, or fiber fragility. Rumination follows a 24-h rhythm and ordinarily mature cows will spend 480 to 540 min/d ruminating under ideal conditions (Van Soest, 1994). A wide range of management factors may depress rumination activity including overcrowding, mixed parity pens, excessive time spent in headlocks, and heat stress. If rumination is chronically depressed by 10 to 20% due to poor management, then we can reasonably predict compromised ruminal function and greater risk for associated problems such as sub-acute rumen acidosis, poorer digestive efficiency, lameness, and lower milk fat and protein output.

In particular, recent research shows that overcrowding influences rumination time, location, and cow posture during rumination (Hill et al., 2009). When cows are fed the same diet, as stall and headlock stocking density is varied from 100 to 142%, rumination time drops by 0.4 h/d, rumination while standing increases by 0.6 h/d, while recumbent rumination decreases 0.9 h/d.

Dominance hierarchy also affects rumination activity. Ungerfeld et al. (2014) compared the rumination activity of high and low ranked dairy cows and found that lower ranked cows ruminated 35% less than higher ranked cows. The lower ranked cows had shorter rumination bouts that reflected lower feed intake. The effect of social interactions within a group of cows on rumination needs to be considered when developing effective grouping strategies for a farm. This is especially important for mixed parity pens where we know that primiparous cows ruminate and lie down less when commingled with mature cows. In fact, we have measured up to a 40% reduction in rumination activity for primiparous cows when they are resting in stalls known to be preferred by dominant cows within a pen (Grant, 2012).

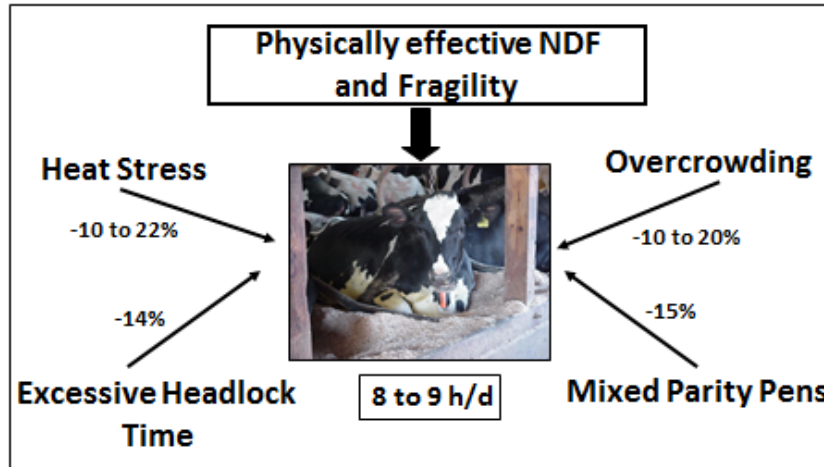


Figure 1. Physically effective NDF and fiber fragility drive rumination, but poor management substantially reduces rumination.

### RUMINATION: MORE THAN SALIVATION

Rumination is an innate behavioral need of dairy cattle (Lindstrom and Redbo, 2000) and they exhibit stereotypies when it is inhibited. When ruminating, whether lying or standing, cows are quiet and relaxed, with heads down and eyelids lowered. Cows prefer to ruminate while lying down (Cooper et al., 2007; Schirmann et al., 2012) with rumination occurring in about 80% of resting bouts. Most rumination occurs at night and during the afternoon. Consequently, poor management that impairs lying time may also reduce rumination. The cow's favored resting posture is sternal recumbency with left-side laterality (55-60% left-side preference). This combination of left-side laterality and upright posture is thought to optimize positioning of the rumen within the body for most efficient rumination (Grant et al., 1990; Albright and Arave, 1997).

Total sleep time in cattle is short, and rumination provides the physiological rest and rejuvenation provided by sleep (Ruckebusch, 1972; Ewbank, 1978). Cattle experience about 3 h/d of non-REM sleep and 45 min/d of REM sleep (Ternman et al., 2012). The EEG patterns recorded during rumination are similar to sleep or somnolence (Bell, 1960). Rumination is closely associated with drowsiness and can even occur when the cow progresses into non-REM sleep. There may in fact be a behavioral continuum between rumination and sleep in ruminants. Sufficient sleep is critical for both metabolic and immune function and the relationships among rumination, resting, and sleep are critical for the health and well-being of dairy cows.

Rumination activity also increases with advancing age as do number of boli and time spent chewing each bolus. Total ruminative chewing increases linearly from 2 years of age forward (Gregorini et al., 2013). This trend toward greater rumination with advancing age may be compensation for reduced chewing efficiency.

## USE OF RUMINATION ON-FARM AS A MANAGEMENT TOOL

Cows ruminate for approximately 450-550 minutes per day and a decrease in rumination time is typically a good sign that something is affecting ruminal function and cow well-being. Specifically, research and on-farm experience indicate that monitoring deviations in rumination from a baseline provides the most useful management information. Rumination often responds to a stressor 12 to 24 h sooner than traditionally observed measures such as elevated temperature or other clinical signs, depressed feed intake, or reduced milk yield (Bar and Solomon, 2010). Recently, on-farm systems have become available to monitor rumination as well as other behaviors such as activity.

Expected changes in rumination time for a variety of management routines and biological processes have been reported based on accumulated on-farm observations with a monitoring system that functions on sound created while chewing (SCR, 2013). Reported deviations in rumination include: calving, -255 min/d; estrus, -75 min/d; hoof trimming, -39 min/d; heat stress, -20 to -70 min/d; and mastitis, -63 min/d (SCR, 2013; Miner Institute data, 2014). A recommended target for making management decisions would be a deviation in rumination of greater than 30 to 50 min/d for either an individual cow or a group. Patterns in the variation in rumination should reflect the feed, feeding management, or the cow's physical and social environment. Key areas to assess would include standard operating procedure compliance, facility limitations, and management routines. Often, changes in rumination measured on-farm reflect changes in feed or feeding management, cow grouping or cow movement, and overall cow comfort.

Common challenges faced by dairy producers that would benefit from routine rumination monitoring include:

- Identifying nutritional problems,
- Finding cows in estrus,
- Detect health problems earlier such as metabolic disorders, mastitis, and lameness,
- Management issues such as grouping, stocking density, or heat stress abatement,
- Modifying traditional fresh-cow checks with less disturbance of cows and time in headlocks, less labor, and greater focus on high-risk cows, and
- Changing treatment and culling decisions because cows can be monitored after treatment to evaluate treatment efficacy.

Importantly, research to-date indicates that it is not necessarily the time spent ruminating each day that must be monitored, but the change in rumination time from day-to-day that is most important.

## Rumination Monitoring and Transition Period

Several recent studies have demonstrated the usefulness of monitoring rumination activity during the periparturient period and in particular the first week of lactation as a means to identify in a timely manner those cows at elevated risk of developing a disease during early lactation (ex. Calamari et al., 2014).

Rumination normally decreases by about 70% at parturition and increases by approximately 50 min/d following calving (Soriani et al., 2012). However, severe inflammation around parturition is associated with a slower increase in rumination time following calving (Soriani et al., 2012). Additionally, more than 90% of cows that had low rumination during the first 3 to 6 days in milk experienced clinical disease in early lactation compared with only 42% for those cows that had greater rumination time. The average rumination time prior to calving was 479 min/d (from -20 to -2 d prepartum), and the value ranged from 264 to 599 min/d (Soriani et al., 2012). For the high-rumination cows during the first week postpartum, the increase in rumination time after calving was very rapid: by 3 days in milk rumination time had reached the average value observed for the entire first month of lactation. In contrast, the lower rumination cows did not reach a stable level of rumination similar to high-ruminators until 15 days in milk.

Earlier research has found that primi- and multiparous cows that have greater lying and ruminating activity for d -2 and -6 prepartum have greater dry matter intake and milk yield on d 1 to 14 postpartum (Daniels et al., 2003). Furthermore, cows with less rumination time prepartum tend to have less rumination time postpartum. Shorter rumination time is also associated with an elevated risk of several metabolic disorders (<420 min/d; Soriani et al., 2012). Figure 2 shows a screen shot from the SCR rumination monitoring system to illustrate how a fresh cow with low rumination activity may be tracked.

Most recently, Stangaferro et al. (2015a) compared prepartum rumination patterns of lactating dairy cows from -7 d to calving that developed health disorders to those cows that did not up to 30 days in milk. For all health disorders combined, rumination time was less for cows with health disorders (439 min/d) than for cows with no health disorders (456 min/d). Rumination time was lowest on the day of calving (391 min) than the 6 d preceding calving (range of 458 to 463 min) for all cows. These researchers concluded that, starting 7 d prepartum, rumination patterns are altered in cows that suffer health disorders within 30 days in milk. Specifically, rumination time is reduced in cows that suffer metabolic disease (such as abomasal displacement, ketosis, or indigestion) and metritis, but not in cows with retained placenta or mastitis.

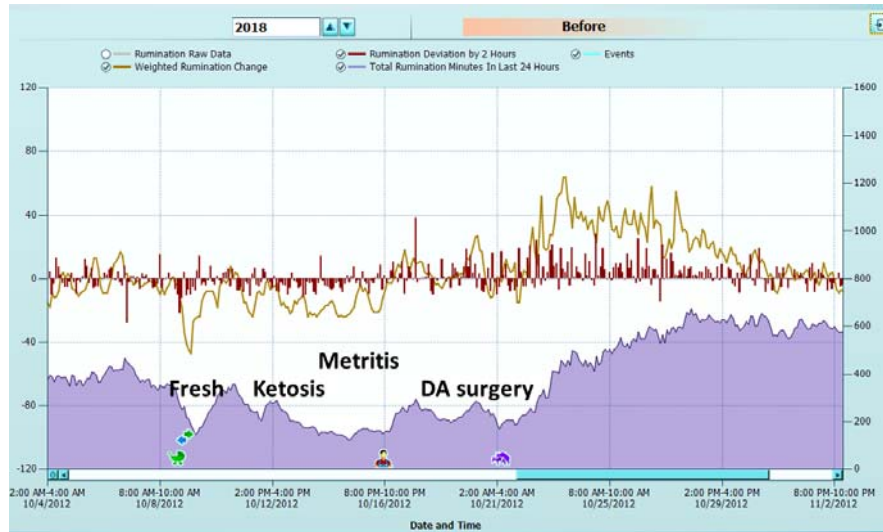


Figure 2. Example fresh cow with low rumination time and associated health problems.

Ability to relate rumination time to mastitis may be related to severity of systemic illness and type of mastitis-causing pathogen (Stangaferro et al., 2015a). Nonetheless, the rumination monitoring system identified cows with abomasal displacement, ketosis, metritis, and mastitis earlier than farm personnel (Stangaferro et al., 2015b). The mean days between clinical sign of disease to the day the disease was flagged by the rumination system was -3 d for abomasal displacement, -1.6 d for ketosis, -0.5 d for indigestion, -0.8 d for metritis, and -0.8 d for mastitis.

This research demonstrates that rumination technology may improve cow care and cow well-being by helping to identify health disorders more quickly. Research and on-farm observations have effectively related rumination activity and mastitis detection (Lacker and Bar, 2013), rumination and estrus (Pahl et al., 2015), rumination and grouping strategy (Grant and Albright, 2001), and rumination and calving pen management (Morrison et al., 2013). The relationship between rumination activity and lameness detection is less certain. Although Van Hertem et al. (2013) found that cows ruminated less at night (8:00 pm to 4:00 am) before being diagnosed as lame, Van Hertem et al. (2014) concluded that hoof trimming per se had relatively small effects on rumination and was dependent on several factors such as parity, stage of lactation, and effect of hoof trimming on subsequent distribution of locomotion scores.

### Rumination and Reproduction

Pahl et al. (2015) found that rumination was reduced for about 30 hours around estrus but the primary drop occurred at 6:00 am on d -1 and noon on d 0. Their research indicates the potential to use changes in rumination as well as feeding times around estrus as a useful aid for early estrus detection. Rumination also shows great potential for monitoring of calving events (Pahl et al., 2014). In this study, cows stopped ruminating  $123 \pm 58$  min before calving and resumed ruminating  $355 \pm 194$  min following calving. Schirmann et al. (2013) found that daily rumination time decreased by about 63

and 133 min during the 24 h before and after calving, respectively. Similarly, feeding time was decreased by about 66 and 82 min per day before and after calving.

## Rumination and Heat Stress

Heat stress negatively affects cow behavior, including rumination. Tapki and Sahin (2006) found that, as air temperature rose from 25 to 40°C, eating decreased 46%, standing increased 34%, locomotion decreased 19%, and rumination decreased by 22%. Higher producing cows (>32 kg/d) were more sensitive than lower producing cows, especially for lying and ruminating activities. More recently, Soriani et al. (2013) observed a negative relationship between daily maximum temperature-humidity index (THI) and rumination time with a reduction of 2.2 min of rumination time for every daily maximum THI unit over 76. Rumination time was negatively related to breathing rate and positively to milk yield. At Miner Institute, we have observed approximately 1 h difference in rumination time for cows that were exposed to minimal heat stress abatement (fans only over the stalls) versus fans and sprinklers over the feed bunk and the free stalls. This strong negative relationship between heat stress and rumination allows us to use rumination monitoring to gage the effectiveness of heat abatement strategies implemented by the producer.

## Current Outlook for Using Rumination Monitoring

Despite the potential effectiveness of rumination monitoring, not all studies have found useful relationships. For example, Liboreiro et al. (2015) concluded that, although differences in daily rumination time and activity between cows that developed periparturient diseases and healthy cows were observed, further research is required to determine how rumination time and activity data can be used to diagnose cows that will develop disease earlier than using standard visual observations. They concluded, as have other research groups, that diagnosis of infectious and metabolic diseases works best when the focus is on change in rumination time from day-to-day.

The bottom line across nearly all of the published research and on-farm observations is that the results verify that rumination monitoring systems may provide predictive and actionable information that farmers can use to improve management of the individual cow, a group of cows, and the whole herd.

## RUMINATION: THE BOTTOM LINE

Rumination is highly sensitive to changes in dietary peNDF and fiber digestibility, cow health and well-being. Its use as a routine on-farm monitoring tool is expected to grow since it will allow earlier identification of problems and more timely intervention.

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