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Rumination Time in Relation to Reproductive Status in Lactating Dairy Cows Fed Partial Mixed Ration Based on Corn Silage

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Abstract: The objective of this study was to characterize the rumination time in lactating dairy cows fed with corn silage. Rumination time was recorded 24 h/day using direct visual observation. Six trials were conducted during 2018, 2019 and 2020, and rumination time was recorded in 480-2-hour periods from 40 Holstein Friesian cows. In each trial, 6 or 8 cows were selected and balanced for days in milk (DIM), milk production and number of lactations. Each cow was recorded continuously for periods of 2 h at a time to complete a full 24-h period per week (12 values per day). Data from all cows were associated with 4 reproductive statuses of cows: Inseminated (1-45 days after insemination), Open (45-150 days after calving), not-pregnant and pregnant. The longest rumination time (RT) was found in pregnant cows (average 536.9 ± 29.87 min/day), and the shortest RT was in open cows (average 420.3 ± 63.2 min/day). Inseminated and non-pregnant cows were found with intermediate values (527.3 ± 82.4 min/day and 467.1 ± 30.7 respectively). Significantly different RT means were found between pregnant and open cows ($p < 0.0001$), pregnant vs. inseminated cows ($p < 0.0001$), and between inseminated and open cows ($p = 0.0005$). We concluded that some gynecological conditions of lactating cows affect the RT. Measurement of RT by visual observations proved to be acceptable for the conditions of this study when cows were housed indoors and were fed with partial mixed ration (PMR) based on corn silage.

Key words: Reproductive status, rumination time, PMR, corn silage.

1. Introduction

Dairy producers, animal nutritionist and veterinarians have long recognized the importance of rumination as an indicator of dairy cattle health and performance. The rumination process allows dairy cattle to eat forage that are not able to be eaten by other non-ruminant animals.

The mechanics of eating and ruminating in cattle are well understood [1]. During eating, the lips, teeth, and tongue of the cow are used to move feed into the month, where is chewed. Feed is chewed by lateral movements of the mandible, resulting in a grinding action that shears, rather than cuts the feed. The feed is chewed by molar teeth on one side of the mouth at a given time [1]. A large amount of saliva is secreted during the eating process to enable a bolus to be formed and swallowed [2].

Rumination is a unique defining characteristic of ruminants. During rumination, digesta from the rumen is regurgitated, re-masticated, and re-swallowed [3].

This cyclical process is influenced by several primary factors including dietary and forage-fiber characteristics, health status, stress, and the cow management environment [4, 5]. Rumination is controlled by the internal environment of the rumen and the external environment of the cow, i.e. the management environment.

Rumination facilitates digestion, particle size reduction, and subsequent passage from the rumen thereby, influencing dry matter intake (DMI). Dairy cows, masticate their feed initially during eating, and swallowed feed is later re-gurgitated and re-masticated

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through the process of rumination [6].

As feed is masticated particles are diminished in size and saliva is secreted to moisturize the bolus and allow swallowing. Saliva plays a crucial role in the digestion and overall health of dairy cows. Some key functions of saliva are:

- buffering rumen pH, for maintaining a stable rumen pH which is essential for the health of the microbial population in the rumen and for efficient digestion;
- lubrication, saliva helps in the formation and swallowing of the feed bolus, making it easier for cows to masticate them and ensuring that feed passes smoothly through the digestive tract;
- enzyme activity, saliva contains small amounts of enzymes like amylase which begin the process of starch digestion in the mouth;
- hydration, saliva helps keep the cow's mouth and rumen dehydrated which is important for the fermentation process in the rumen and the overall digestion of feed;
- waste excretion, saliva can help in the secretion of certain waste products from the bloodstream into the digestive tract.

Physical division of feed into smaller parts during mastication facilitates microbial colonization and passage of small particles from the rumen through the lower gastrointestinal tract.

Chewing behavior of the dairy cows is controlled and modulated by a combination of animal factors (health and stress level), management environment (balance of eating, ruminating, and resting), and physico-chemical properties of the diet (neutral detergent fiber (NDF) × starch) [7]. All factors interact, and successful herd management will search for optimum forage-fiber characteristics, ration formulation, management environment, and the health status of the cows [7].

Rumination is positively related to feeding time and DMI. Following periods of high feed intake, cows spend more time ruminating. Restriction feed intake reduces rumination; a 1-kg decrease in DMI has been associated with a 44 min/day reduction in rumination.

Rumination activity has been 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 [8]. As the level of peNDF increases in the diet, the cow is stimulated to ruminate more [9].

Under acute and chronic stress environments, rumination is depressed. Several key components of the management environment that may reduce the cow's expected rumination response to dietary peNDF, fiber digestibility or fiber fragility are: heat stress (-10% to -22%), overcrowding (-10% to -20%), excessive head lock (-14%), mixed parity pens (-15%) [10].

Under ideal conditions mature cows will spend 480 to 540 min/day ruminating [11]. If rumination is 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, poor digestive efficiency, lameness, lower milk fat and protein output [10].

Dominance hierarchy also affects rumination activity, lower ranked cows ruminated 35% less than higher ranked cows [12]. The effect of social interactions on rumination needs to be considered in grouping strategies for a farm; primiparous cows ruminate and lie down less when mixed with mature cows. Grant and Moner [13] measured up to a 40% reduction in rumination activity for primiparous cows when they were resting in stalls known to be preferred by dominant cows within a pen.

Cows prefer to ruminate while lying down [14, 15]. Most rumination occurs at night and during afternoon. When ruminating, whether lying or standing, cows are quiet and relaxed, with heads down and eyelids lowered. The cow's favored resting posture is sternal recumbency with left-side laterality (55%-60% left-side preference). The left-side laterality and upright posture is thought to optimize positioning of the rumen within the body for most efficient rumination [16, 17].

Rumination activity also increases with advancing age as do number of boli and time spent chewing each bolus [10]. Total ruminative chewing increases linearly from 2 years of age forward [18].

A decrease in rumination time is a good sign that something is affecting ruminal function and cow well-being. Rumination often responds to a stressor 12 to 24 h sooner than traditionally observed such as elevated body temperature, depressed feed intake or reduced milk yield [19].

Changes in rumination time for a variety of management routines and biological processes have been reported based on accumulated on-farm observations with diverse monitoring systems such as visual observation (VO), automated systems (transducer that transformed jaw movements into electrical signals), pressure sensors, pneumatic systems or microphone-based monitoring system [20].

Cows ruminate for approximately 500-550 min/day, and reported deviations in rumination include: calving—255 min/d; estrus—75 min/d; hoof trimming—39 min/d; heat estrus—20 min/d to 70 min/d and mastitis—63 min/d [20, 21]. The 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 of cows [10]. Often, changes in rumination measured on-farm reflect changes in feed or feed management, cow grouping or cow movement, and overall cow comfort. It is not necessary to monitor the time spent ruminating each day, but the change in rumination time from day to day is most important.

Zebeli et al. [22] reported a mean ruminating time of 434 min/day (n = 99) ranging from 151 to 630 min/day, and White et al. [23] reported a mean ruminating time of 436 min/day (n = 179), ranging from 236 to 610 min/day. Also, Mikula et al. [24] reported a low rumination time (up to 412 min/day), medium rumination time (from 412 to 527 min/day), and high rumination time (above 527 min/day) in their study of a total of 365 high-yielding multiparous dairy cows covering 24-304 days of lactation.

Currently, several companies produce commercially available rumination monitoring systems. The rumination sensor is usually integrated into activity monitor devices, ear tags or neck collars. Some rumination monitoring systems use a bolus placed in the rumen of the animal or a pressure sensor located on a nose band. Numerous independent research studies have validated the accuracy and precision of some systems on the market ([25, 26] for CowManger SensoOr ear tags, [27], [28] for SCR Hi-Tag neck collars).

In recent years, there has been an increase in research studies regarding using rumination as an indicator of changes in animal performance and welfare.

Activity and rumination monitoring systems are growing in popularity, but their on-farm applications are mostly focused on management of reproduction and health.

Information regarding effects of gynecological status of dairy cows on their rumination time are scarce. The objective of this study was to characterize the rumination time in relation to reproductive status in lactating dairy cows fed with corn silage.

2. Materials and Methods

2.1 Animals and Management

Dairy cows used in this experiment were located at Agricultural Research and Development Station (ARDS), Șimnic-Craiova, Romania. The experiment was performed in compliance with European Union Directive 86/609/EC on Holstein Friesian dairy cattle. The research dairy farm is located in the South-West region (Oltenia, 182 m above sea level, 44°19′ N, 23°8′ E). The initial dairy herd was imported from Denmark (1977-1978) as Danish Black and White (DBW) dairy cattle. Today the most genes from the original DBW cattle have been replaced by Holstein Friesian genes as a result of a long and large genetic improvement program. The dairy farm has a 140-cow Holstein Friesian milking herd. In a previous paper

[29], we reported the rumination time and its association with milk yield and composition in dairy Holstein Friesian cows fed with corn silage. Visual observation was the standard method to measure rumination time [28]. Six trials were conducted during 2018, 2019 and 2020. On short, the procedure consisted of direct observations by two trained research observers.

Rumination was defined as the time a cow spends chewing a regurgitated bolus until it swallows back. In each trial, 6 cows or 8 cows were selected and balanced for days in milk (DIM), milk production and number of lactations. All cows were housed indoors (loose housing) in contiguous pens, that share identical characteristics: area of feed and water troughs, and rest area with straw (5 m^2/cow). Each cow was recorded continuously for periods of 2 h at time to complete a full 24-h period per week. The observers were standing in places of the house where rumination behaviour of a specific cow (identified with a unique number by a colour spray), was easily recorded and the observer's presence had no effect on the cow's routine and behaviour. All cows were fed a partial mixed ration (PMR) (Table 1): corn and silage, alfalfa hay fodder beet and concentrate mix.

Additional concentrates were fed to milk yield in the house. Water was supplied at libitum and was twice daily at 06:00 and 17:00 with DeLaval 2×5 system.

2.2 Measurements and Data Collection

Rumination time was recorded in 480-2 h-periods from multiparous cows (n = 40) and all were used for analysis. The cows were classified as belonging to the following gynecological status groups: Inseminated 1-45 days after insemination (n = 11), Open 45-150 days after calving (n = 9), not pregnant (n = 7), and pregnant (n = 13).

Individual animals were unique to each trial and were divided into 2 groups to ensure similar parities and DIM.

Forage, concentrate and PMR representative samples were collected for analysis using wet chemistry. The particle size distribution of PMR samples was determined using Penn State Particle Separator System with 3 sieves (19 mm, 8 mm and 1.18 mm) and a bottom pan [30] and shaken at a frequency of 1.1 Hz. The mean retention of particle was: 6% for sieve > 19 mm, 48% for sieve 8-19 mm, 45.5% for sieve 1.8-8 mm, and 5.5% for sieve < 1.18 mm.

Table 1 Average ingredients and nutrient composition of PMR and concentrates.

PMR ingredients (fresh weight PMR proportion)	
Corn silage	57.8%
Alfalfa hay	3.8%
Concentrate mix	29.8%
Fodder beet	8.5%
Nutritional value/kg of dry matter (DM)	
Net energy lactation	1.51 Mcal/kg DM
Crude protein	148 g/kg DM
Rumen un-degradable protein	33%
NDF	348 g/kg DM
Acid detergent fiber	228 g/kg DM
Non-fiber carbohydrates	380 g/kg DM
Additional concentrate	
Net energy lactation	1.9 Mcal/kg DM
Crude protein	260 g/kg DM

Table 2 The average, median, quartile 1 and quartile 3 for each reproductive status category of dairy cows.

Cow reproductive status category	*n*	%	Quartile 1 (min/day)	Median (min/day)	Average ± SD (min/day)	Quartile 3	Coefficient of variation (%)
Inseminated	11	27.5	482	566	527.3 ± 82.4	583.5	15.6
Open	9	22.5	362	450	420.3 ± 63.2	460	15
Not pregnant	7	17.5	437	488	461.1 ± 30.7	491	6.5
Pregnant	13	32.5	515	524	536.9 ± 29.9	568	5.5
Overall	40	100	449.5	504	497.5 ± 72.7	564.5	14.6

Table 3 Comparison of rumination true means between reproductive status categories of dairy cows.

	Difference	95% CI	DF*	Significance level
Pregnant vs. Nonpregnant cows	-69.8	-99.5 to -40	18	$p < 0.0001$
Pregnant vs.** Open cows	-116.6	-158.4 to 74.8	20	$p < 0.0001$
Pregnant vs. Inseminated cows	-9.6	-60.4 to -41.2	22	$p = 0.6988$
Inseminated vs. Open cows	-107	-177.3 to -36.6	18	$p = 0.0050$
Inseminated vs. Nonpregnant cows	-60.2	-129.7 to 9.3	16	$p = 0.0849$
Nonpregnant vs. Open cows	-46.8	-102.8 to 9.2	14	$p = 0.0948$

* DF = degrees of freedom; ** vs. = versus.

2.3 Statistical Analysis

The data were entered into Microsoft Excel computer program, 2007. STATA Version 14 was used to summarize the data and descriptive statistic was used to express the results. The *p*-values obtained for the difference between the estimated means for rumination of cow groups were calculated with Med. Calc. Software [31].

3. Results

Overall, the average rumination time was 497.5 min/day ranging from 311 to 594 min/day. Based on individual cow average daily rumination time, we reported three groups of cows: low rumination cows (mean 402.7 ± 28.4 min/day), medium rumination cows (mean 508.8 ± 31.6 min/day) and high rumination cows (mean 581.1 ± 9.2 mi/day) [29]. In this report, we associated rumination time of cows with their reproduction status category (inseminated, open, not pregnant and pregnant) (Table 2).

The longest rumination time was in pregnant cows (average 536.9 ± 29.87 min/day), and the shortest was in open cows (average 420.3 ± 63.2 min/day).

Significantly different rumination time means were found between pregnant and nonpregnant cows ($p < 0.0001$) and between pregnant and inseminated cows ($p < 0.0001$) (Table 3). Also, the difference between inseminated vs. open cows was large (-107 min/day) and the significance level was $p = 0.005$ (Table 3).

4. Discussion

Rumination time was recorded in 480-2-h-periods from all 40 dairy cows. We hypothesized that rumination time can be affected by individual animal reproduction status in lactating cows.

According to our study, the longest rumination time (RT) was evaluated in pregnant cows (average 536.9 ± 82.4 min/day). The average rumination time was 69.8 min longer for pregnant cow category in comparison with nonpregnant cow category (average 467.1 ± 30.7 min/day), and with 116.6 min longer in comparison with open cows (average 420.3 ± 63.2 min/day). Overall average of RT was 497.5 ± 72.7 min/day. Cow RT is modulated by a combination of animal factors, management environment and physicochemical properties of the diet, particularity fiber [7]. The coefficient of variation (CV) for rumination time among all cows was 14.6% (Table 2). Byskov et al. [32] reported that approximately 32% of the variation in daily RT could be explained by variation intake of the dietary fractions, where as 48% of the total variation in

RT was accounted for by individual variation between cows in automatically recorded rumination time.

Optimum rumination time is needed to minimize the risk of rumen acidosis, enhance fiber digestion and promote high levels of feed intake in dairy cows [6]. The physiological maximum rumination time is about 10 to 12 h/day for cattle feed high-fiber diets. Animals with a greater intake capacity seem to chew feed more efficiently. Heavier animals can cope with relatively more fiber as a result of relationship of rumination capacity and body size, which is near unity.

Heavily pregnant cows spent more time ruminating after periods of high feed intakes [33], and this can explain the high time rumination observed in pregnant cows in this study. And average RT in dairy cow without disease and stress was estimated to be 522 min/day in primiparous cows [34].

Open cows were cows not observed in oestrus and included cyclic (suboestrus or weak oestrus behavior and insufficient observation), and non-cyclic (inactive ovaries) cows. In this reproductive status the cows have some specific reproductive disorders such as cystic ovarian disease, persistent corpus Luteum/Pyometra, time anoestrus, and the treatments of this provoke stress. In our study open cow's category had the shortest RT (420.3 ± 63.2 min/day), with 116.6 min/day less comparing with pregnant category cows.

Inseminated category cows are cows artificial inseminated with 1 to 45 days after insemination. In this study the rumination time of cows did not differ comparing with pregnant category cows (527.3 ± 82.4 min/day vs. 536.9 ± 29.9 min/day).

Significantly different rumination time (RT) means were found between inseminated category cows and open category cows ($p = 0.005$; Table 3).

Rumination is found to be voluntarily controlled by the animal, and the animal will stay to ruminate if it is disturbed [35]. The inseminated category cows were able to perform their RT needs in loose housing system and fed with PMR.

Cow comfort and forage quality must comprise a system. For this system, it is necessary to choose an optimum forage particle size, NDF degradability or fragility and dietary forage percentage that allow the cow to consume her daily DMI within 3-5 h/day of eating time and to be paired with cow to be resting area, where cows can easily lie down and ruminate.

Grant and Cotanch [7] recommended 50%-60% of particle retained on the 8 mm sieve of the Penn State Particle Separation (PSPS). In our study the particle retained on the 2 mm sieve was 48%.

The particles retained on 8 mm sieve optimize eating time, DMI and minimize sorting risk while effectively stimulating rumination.

5. Conclusions

Measurement of rumination time by visual observations proves to be acceptable for the conditions of this study, when cows were housed indoors and were fed with PMR.

The results confirmed the hypothesis that some gynecological conditions of dairy cow, may affect rumination time.

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