Research Open

Integrative Journal of Veterinary Biosciences

Volume 6 Issue 1

Research Article

Rumination Behavior and Its Association with Milk Yield and Composition of Dairy Cows Fed Partial Mixed Ration Based on Corn Silage

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Received: March 29, 2022; **Accepted:** April 04, 2022; **Published:** April 14, 2022

Abstract

The objective of this study was to characterize the variation in rumination time and its association with milk yield and composition in dairy Holstein Friesian cows fed with corn silage. Rumination time was recorded 24 h/day using direct visual observation. Cows were divided into 2 groups to facilitate the visual observation and to ensure similar parties, days in milk (DIM) and milk yields between groups of cows. All the cows were fed with a partial mixed ration (PMR) based on corn silage. Rumination was defined as the time cow spends chewing a regurgitated bolus until it swallows back. Each cow was recorded continuously for periods of 2 hours at a time to complete a full 24 hours (12 values per day). Data from cows were assigned to three groups: based on individual cow average daily rumination time – low rumination cows up to 451 min/day (L=up to 25th rumination percentile), medium rumination cows from 451 to 566 min/day (M=between the 25th and 75th percentile) and high rumination cows above 566 min/day (H from the 75th percentile). Cows from all the groups (H. M. L.) ruminated approximately 497.5 min/day ranging from 311 to 594 min/day. High rumination cows (mean 581 min/day) produced 4.05% more energy corrected milk (ECM) compared with L rumination cows (mean 403 min/day). Rumination time was found to be positively associated with milk yield of cows fed a PMR based on corn silage.

Keywords: *Corn silage, Holstein Friesian cow, Milk production, Partial mixed ration, Rumination behavior*

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 intro the mouth. 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 the molar teeth on one side of the mouth at 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, remasticated and reswallowed [3]. This clinical 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 facilities digestion, particle size reduction and subsequent passage from the rumen thereby, influencing dry matter intake. Rumination also stimulates salivary secretion and improves ruminal function buffering [6]. Rumination is positively related to feeding time end dry matter intake (DMI). Following periods of high feed intake, cows spend more time ruminating. Restriction feed intake reduces rumination a 1-kg decrease in dry matter intake (DMI) has been associated with a 44 min/day reduction in rumination [7].

Rumination activity has been consistently associated with intake of physically effective NDF (peNDF) which combines dietary particle length and dietary Neutral Detergent Fibre (NDF) content and is directly related to chewing activity and rumination [8]. As the level of peNDF increases in the diet the cows is stimulated to ruminate more [9]. Under acute and chronic stress environments, ruminations 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 leek (-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 and 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 are mixed with mature cows. Grant (2012) [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 with lying down [14,15]. Most rumination occurs at night and during afternoon. When ruminating, whether lying or standing, cows are quiet relaxed, with heads down and eyelids lowered. The cow's favorite 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 hours sooner than traditionally observed measures 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 (V.O.), automated systems (transducer that transformed jaw movements into electrical signals), pressure sensors, pneumatic systems or microphone-based monitoring system [20]. Deviations in rumination from a baseline provides useful management information.

Cows ruminate for approximately 500-550 minutes per day and reported deviations in rumination include: calving – 255 min/day; estrus – 75 min/d; heaf trimming – 39 min/d; heat stress – 20 to 70 min/d and mastitis – 63 min/d [20]. 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 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 necessarily to be monitored the time spent ruminating each day, but the change in rumination time from day-to-day it is most important.

Currently, several companies produce commercially available rumination monitoring systems. The rumination sensors are 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 sonsor located on a nose band. Numerous independent research studies have validated the accuracy and precision of some systems on the market ([21,22] for CowManger Sensoor ear tags and [23,25] 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 [25].

The objective of this study was to characterize the variation in rumination time and its influence on milk, fat and protein production in dairy Holstein Friesian cows.

Material and Methods

Animals

Dairy cows used in this experiment were located at Agriculture Research Development Station (ARDS) Simnic – Craiova, Romania. The experiment was performed in compliance with European Union Directive 86/609/Ec. on Holstein Friesian dairy cattle that belonged to a long and large genetic improvement program. The dairy farm has a 140 – cow Holstein Friesian milking herd. Six trials were conducted during 2018, 2019 and 2020.

Trial 1 (January, 2018): Six multiparous milking cows were selected and balanced for days in milk (DIM: mean ± SD 101.5 ± 4.3 days), milk production (9219.3 ± 279.7 kg) and number of lactation (L=3). The cows were then allocated to 2 different groups: group 1(G1) DIM 97.6 ± 1.7 d and milk production 9024.6 kg and groups 2 (G2) DIM 105.3 ± 3.0 d and milk production 9414.0 ± 200 kg, with 3 cows in each group. Each group was housed (loose housing) in contiguous pens that share identical characteristics: area of feed and water trough, rest area with straw (5 m^2/cow). Cows were fed with a partial mixed ration (PMR): corn silage 60% (fresh weight PMR proportion) alfalfa hay 3% concentrate mix 30% and fodder beet 7% with additional concentrate fed to yield in the house. Water was supplied at libitum. The cows were milked twice daily at 06:00 and 17:00.

Trial 2 (November 2018): Six multiparous milking cows were selected and balanced for DIM 103.3 ± 2.2, milk production 9011.6 ± 106.3 kg number of lactation (L=3). The cows were than allocated to 2 different groups: groups 1 (G1) DIM (104 ± 2 days), milk production (8923.3 ± 66.6 kg) and number of lactation (L=3) and G2 DIM (102.6 ± 2.5 d), milk production (9100 ± 20 kg) and number of lactation (L=3) with 3 cows in each group, housed (loose housing) in contiguous pens that share identical characteristics: area of feed and water troughs, rest area with straw and exercise area. Cows were fed with a partial mixed ration (PMR): corn silage 58% (fresh weight PMR proportion), alfalfa hay 3%, concentrate mix 32% and fodder beet 7%, with additional concentrate fed to yield in the house. Water was supplied ad libitum, and cows were milked twice daily at 06:00 and 17:00.

Trial 3 (February 2019): Six multiparous milking cows were selected and balanced for DIM (97.5 ± 189.2 kg) and number of lactation (L=4). The cows were allocated to 2 different groups: G1 DIM (97.3 ± 1.5 d), milk production (8806.7 ± 162.9 kg) and number of lactation (L=4) and G2 DIM (97.6 ± 2.5 d), milk production (9060 ± 12.6 kg) and number of lactation (L=4), with 3 cows in each group. Each group was housed in the same pens as in trial 2. Cows were fed a PMR (corn silage 56 %, fresh weight PMR proportion) alfalfa hay 4% concentrate mix 30% and fodder beet 10%, with additional concentrate fed to yield in the house. Cows were milked twice daily at 06:00 and 17:00.

Trial 4 (December 2019): Eight multiparous milking cows were selected and balanced for DIM (109.6 ± 2.6 days), milk production

8978.7 ± 135 kg and number of lactation (L = 3). The cows were allocated to 2 different groups: G1 DIM (108 ± 1.8), milk production (8895 ± 147.3) and number of lactation (L = 3) and G2 DIM (111.2 ± 2.5) and number of lactation (L =3) with 4 cows in each group. Each group was housed (loose housing) in contiguous pens that share identical characteristics: area of feed and water troughs, rest area (5 m^2/cow) with straw and exercise area (5 m^2/cow). Cows were fed with a PMR: corn silage 60% (fresh weight PMR proportions), alfalfa hay 4%, concentrate mix 28% and fodder beet 8%, with additional concentrate fed to milk yield in the house. Water was supplied at libitum. The cows were milked twice daily at 06:00 and 17:00.

Trial 5 (February 2020): Six multiparous milking cows were selected and balanced for DIM (119.8 ± 5.4 d), milk production (8866.6 ± 169 kg) and number of lactation (L = 4). The cows were allocated to 2different groups: G1 DIM (116 ± 4 d), milk production (8960 ± 158.7 kg) and number of lactation (L = 4), and G2 DIM (123.6 ± 3.8), milk production (8773.3 ± 141.9 kg) and number of lactation (L = 4), with 3 cows in each group. Each group was housed (loose housing) in contiguous pens as in trial 2.

Cows were fed a PMR: corn silage 57% (fresh weight PMR proportion) alfalfa hay 4%, concentrate mix 30% and fodder beets 9% with additional concentrate fed to milk yield in the house. Cows were milked twice daily at 06:00 and 17:00. Trial 6 (November 2020): Eight multiparous milking cows were selected and balanced for DIM (116.3 ± 6.1 d), milk production (8620 ± 141.7 kg) and number of lactation (L = 4). The cows were allocated to 2 different groups: G1 DIM (111.3 ± 3 d), milk production (8575 ± 121.5 kg) and number of lactation (L = 4), and G2 DIM (121.3 ± 3 d), milk production (8665 ± 163.4), and number of lactation (L = 4) with 4 cows in each group. Each group was housed in the same pens as in trial 4. Cows were fed a PMR: corn silage 56% (fresh weight PMR proportion), alfalfa hay 5%, concentrate mix 29% fodder beet 10%, with additional concentrate fed to milk yield in the house. Water was supplied ad libitum and cows were milked twice daily at 06:00 and 17:00.

In this experiment cows were divided into 2 groups to facilitate the visual observation and to ensure similar parties, DIM and milk yields between groups of cows. All the cows were identified with a unique number by color spray. After milking cows received a minimum of 0.5 kg and a maximum 5 kg of concentrate per cow and day. Cows were given 2 weeks to adapt with diet and house and the measurements were taken in the third week.

Data Collection

Visual observation is the standard and more reliable method to reassure rumination [24]. This can be done either through direct observation or by analysis of video recordings.

In this experiment we used direct observation by a trained research personnel; one for G1; observer 1, and one for G2; observer 2.

All cows were housed indoors. The observers were standing in places of the house where all the behaviors of a specific cow were easily recorded and the observer's presence had no effect on the cow's routine and behavior [24]. Behaviors (eating, drinking, idling, and ruminating), were recorded according to the ethogram ([24], Table 1). Rumination was defined as the time a cow spends the time a cow spends chewing a regurgitated bolus until it swallows back. Each cow was recorded continuously for periods of 2 hours at a time to complete a full 24 hours period per week.

Daily milk production was obtained from the farm management system (DeLaval 2x5), and fat and protein content was analysed in the laboratory with Ekomilk Ultrasonic Milk Analysers (Bultuh 2000 LTD). Fat and protein contents were used for calculating energy-corrected milk (ECM). The ECM was calculated according to Reist et al., (2002) [26] as [(0.038 x g crude fat + 0.024 x g crude protein + 0.017 x g lactose)] x kg milk/3.14.

Forage, concentrate and PMR representative samples were collected for analysis using wet chemistry. The particle size distribution of PMR samples was determined using. Pen State Particle Separator system with 3 sieves (19 mm, 8 mm, 1.18 mm and a bottom pan) [27]. The mean retention of particle were: 6% > 19 mm, 48% 8-19 mm, 40.5% 1.8-8 mm, and 5.5% < 1.18 mm. PMR and concentrates ingredients and nutritional value are shown in Table 2.

Concentrate mix and additional concentrate based on soybean meal, sunflower, corn, wheat and barley grains and minerals, vitamins and feed additives.

Table 1: Behavioral ethogram used in trials 1 to 6.

Behavior	Definition
Eating	Cow head over or in the feed trough
Drinking	Cow head over or in the water trough
Ruminating	Time the cow spends chewing a regurgitated bolus until swallowing back
Idling	No ruminating, eating or drinking behaviour

Table 2: 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:	
Net Energy Lactation	1.51 Mcal/kg DM
Crude protein	148 g/kg DM
Rumen undegradable protein	33%
Neutral detergent fiber	348 g/kg DM
Acid detergent fiber	228 g/Kg DM
Non-fiber carbohydrates	380 g/kg DM
Concentrate mix:	
Net energy lactation	1.7 Mcal/ kg DM
Crude protein	230 g/kg S.U.
Additional concentrate:	
Net energy lactation	1.9 Mcal/kg DM
Crude protein	260 g/kg S.U.

Statistical Analysis

The data were entered into Microsoft Excel computer program 2007 – STATA Version 14 was used to summarize the data and descriptive statistics were used to express the results. The p-values obtained for the difference between the estimated means for rumination group were adjusted using Tukey's method.

Results and Discussion

Rumination behavior was recorded in 480 – 2 – hour – periods from all cows (n = 40) and all were used for the analysis to determine their influences on milk performance of Holstein Friesian cows. Data from cows were assigned to three groups based on individual cow average daily rumination time: low rumination cows up to 451 min/day (L = up to 25th rumination percentile), medium rumination cows from 451 to 566 min/day (M between the 25th and 75th percentile) and high rumination cows above 566 min/day (H. from the 75th percentile). Each observer recorded rumination data in 2 hours intervals (i.e., 12 values per day), and rumination time was measured in minutes recorded within each 2 – hour interval. The daily rumination time of cow was calculated by adding 12 measurements of the day.

Differences in rumination time were observed between all the three groups: L (402.7 ± 28.4 min/day), M (508.8 ± 31.6 min/d) and H (581.1 ± 9.2 min/day).

Daily pattern of rumination time expressed in minutes per 2 – hour intervals for all three groups of cows is presented in Figure 1. The means rumination time for L, M and H groups of cows were 33.6 minutes, 42.4 minutes and 48.4 minutes respectively per 2 hours. Most rumination activity occurs during night (Figure 1). The system used in our trials to measure Rumination Time (RT) allowed us to record the pattern of RT during daytime and night time.

High rumination cows had a mean milk production of 27.76 kg compared with the M and L groups (27.5 kg and 27.2 kg, respectively; Table 3). Low rumination cows had a mean milk fat percent of 3.51% compared with the M and H groups (3.58% and 3.61%, respectively). High rumination cows had a mean milk protein percent of 3.15% compared with the M and L groups (3.11% and 3.04% respectively).

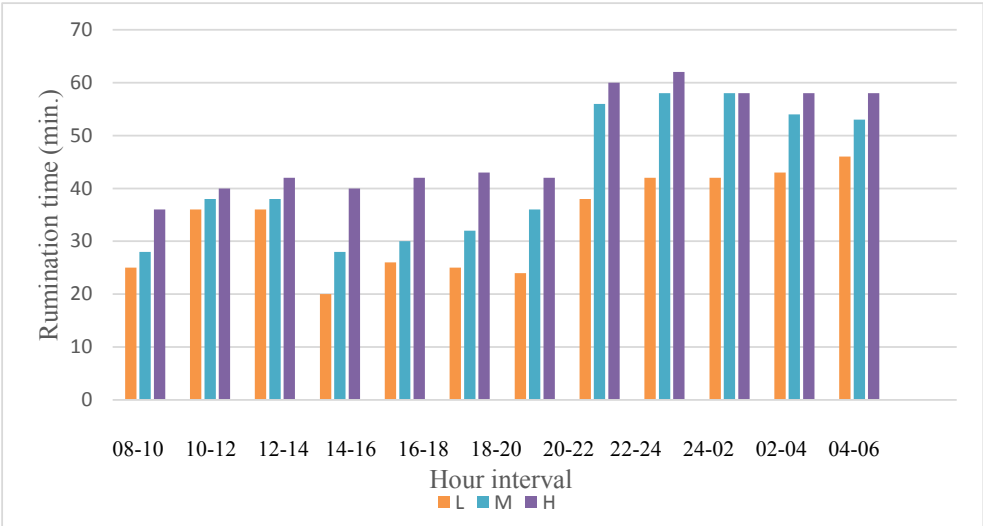
The fat and protein ratio was higher in high rumination cows (1.16) compared to the Low (1.15) and medium (1.15) rumination cows 5 (Table 3). High rumination cows had an effect on milk production (1.7% more milk) compared with Low rumination cows. Also, high rumination cows produced 4.05% more ECM compared with low rumination cows, and 1.17% more ECM compared with medium rumination cows (Table 3). Medium rumination cows produced 1.03% more ECM compared with low rumination cows.

Mean fat percent of High rumination cows was 3.61% compared with 3.58% and 3.51% for medium rumination cows and low rumination cows respectively. Mean fat: protein ratio of High rumination cows was 1.16 compared with 1.15 for medium and low rumination cows. Cows from all the groups (H, M and L) ruminated approximately 497.5 min/day ranging from 311 to 594 min/day.

Table 3: Means rumination time and milk production low (L), medium (M) and high (H) ruminations cows.

	Rumination groups		
	L	M	H
Rumination time (min/day)	402.7 ± 28.4^{a}	508.8 ± 31.64^{b}	581.1 ± 9.24^{c}
Milk (kg/day)	27.200^{a}	27.500^{b}	27.670^{b}
ECM (kg/day)	24.950^{a}	25.660^{b}	25.960^{c}
Fat (%)	3.51^{a}	3.58^{b}	3.61^{b}
Protein (%)	3.04^{a}	3.11^{b}	3.15^{c}
Fat: protein	1.15^{a}	1.15^{a}	1.16^{b}

The means within a row with different superscripts differ ($p < 0.05$).



L	25	36	36	20	26	25	24	38	42	42	43	46	33.6*
M	28	38	38	28	30	32	36	56	58	58	54	53	42.4
H	36	40	42	40	42	43	42	60	62	58	58	58	48.4

* mean in minutes per 2 hours

Figure 1: Daily pattern of rumination time expressed in minutes per 2 hours intervals for all three groups of cows (L = green bars; M = blue bars and H = yellow bars).

White et al., 2017 [28] reported a mean rumination time of 436 min/day ranging from 236 to 610 min/day. Zetouni et al., 2018 [29] recorded 443 min/day in Danish Holstein cows. A positive relationship between rumination time and milk production in early lactation was reported by Soriani et al., 2013 [30]. Main factors of rumination time are connected with the chemical and physical characteristics of the diet. Beauchemin et al. [31] described a positive relationship between rumination time and dry mater intake in dairy cows.

An increase in rumination time should be directly connected with better rumen homeostasis and fiber microbial degradation and an increase in fat percentage [9].

Rumination time had a slight effect on milk protein percentage (3.15% for High rumination cows compared with 3.11% and 3.04% for Medium and Low rumination cows respectively). Kaufman et al., [32] found no association between milk protein and rumination time in dairy cows in early lactation.

Conclusion

Measurements of RT obtained by direct visual observation proved to be acceptable for the conditions of this study when cows were housed inside the shed. Rumination time was found to be positively associated with milk yield of dairy fed with a PMR based on corn silage. Further research is needed to support the use of RT as predictor for milk yield different conditions.

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Citation:

Constantin G, Mihaela R (2022) Rumination Behavior and Its Association with Milk Yield and Composition of Dairy Cows Fed Partial Mixed Ration Based on Corn Silage. *Integr J Vet Biosci* Volume 6(1): 1-5.