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Original article

Evaluation of rumination time, subsequent yield, and milk trait changes dependent on the period of lactation and reproductive status of dairy cows

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Abstract

The aim of this research was to determine rumination time (RT) and the subsequent milk yield, along with trait changes during lactation dependent on the reproductive status of dairy cows.

728 cows were selected for evaluation in regards to 1–150 days of milk production (DIM). According to their period of lactation and reproductive status, the cows were selected for the following groups: Inseminated (1–35 days after insemination, n=182), Open (45–90 days after calving, n=126), Fresh (1–44 days after calving, n=45); Not-pregnant (>35–60 days after insemination and not-pregnant, n=55); Pregnant (35–60 days after insemination and pregnant (n=320). The animals were milked with Lely Astronaut® A3 milking robots. The daily milk yield, rumination time, bodyweight, milk composition (fat, protein, lactose, somatic cell count and gynecological status date) were collected from the Lely T4C management program for analysis.

We estimated the lowest productivity in the pregnant cows, where the average milk yield was 28.72 kg and the highest productivity in the fresh cow ($p<0.001$) (Table 1). The longest rumination time was determined for the inseminated cows, statistically significantly higher at 9.92% ($p<0.001$) than in the non-pregnant cows, whose rumination time was the shortest. The statistically reliably RT positively correlated with productivity ($r=0.384$, $p<0.001$) of the cows (from $r=0.302$ in the second lactation and $r=0.471$ in the first lactation to $r=0.561$ in multiparous cows; $p<0.001$). Rumination time, according to groups of cows by milk yield, had a tendency to increase (2.14 times) from 202.0± 87.38 (in cows with a productivity of less than 10 kg milk) to 431.6±33.91 (in cows with a milk yield higher than 50 kg) by the linear regression equation: $y = 38.02x + 232$, $R^2 = 0.721$ ($p<0.001$). The relation between the gynecological status and milk fat-protein ratio of the cows was statistically significant ($\chi 2=2.974$, df= 8, $p<0.0001$). The longest rumination time was determined for the inseminated cows (1 – 35 days after insemination), and the shortest for the not-pregnant cows (>35 – 60 days after insemination and not-pregnant).

We can conclude that rumination time, subsequent yield, and milk trait change depends on the period of lactation and reproductive status of a dairy cow.

Key words: cow, rumination, milk yield, reproduction

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Introduction

Rumination is a cyclical process characterized by regurgitation, remastication, and reswallowing. One important function of rumination is to facilitate digestion, particle size reduction, and the subsequent passage of feed from the reticulorumen while maintaining high levels of feed intake. Furthermore, rumination increases saliva secretion and improves rumen functionality because saliva aids in buffering the volatile fatty acids produced by microbial digestion (Beauchemin 1991). Rumination is affected by diet characteristics and nutritional factors such as dietary composition and, in particular, digestibility of the feed, neutral detergent fibre (NDF) intake, and forage quality (Welch and Smith 1970). The rumination time (RT) is reduced by acute stress (Herskin et al. 2004), as well as anxiety (Bristow and Holmes 2007), disease (Welch 1982, Hansen et al. 2004), and greater stocking density (Grant and Albright 2001). Rumination time (RT) is an appropriate parameter for early identification of metabolic disorders such as ruminal acidosis. Saliva secretion and rumen health are closely associated with the daily RT (Maekawa et al. 2002). In addition, Murphy et al. (1983) have found that the RT could be used for the monitoring of ration composition and feeding practices. In the past, researchers demonstrated the positive relationship between NDF intake and RT, and showed that reduced feed intake during late pregnancy increased the risk of calving diseases (Kim and Suh 2003, Urton et al. 2005, Adin et al. 2008, Trevisi et al. 2010). The feeding and ruminating behaviour of dairy cows decreases gradually in the last two weeks before calving, and drops suddenly at calving (Bar and Solomon 2010). Time spent on feeding also decreases, dry matter intake tends to decrease slightly (Schirmann et al. 2013), and activity changes in the last 24 h before calving (Saint-Dizier and Chastant-Maillard 2015). Titler et al. (2015) have demonstrated that an activity index could be used to predict whether a cow would calve within 6 h following an increase in its activity index. Sensors seem capable of detecting these changes (Bar and Solomon 2010, Schirmann et al. 2013). The typical method to monitor rumination is through visual observation, either taken live (Couderc et al. 2006) or from video (Lindström et al. 2001), and recently, new indirect methods based on the analysis of vocal signs (HR-Tag rumination monitoring system, SCR Engineers Ltd., Netanya, Israel) have been used. Recently, a rumination monitoring system (RMS; RuminAct-Milkline, Gariga di Podenzano, Italy), which records the RT by the sound pattern of regurgitation and rhythmic jaw movements during the rumination activity, has enabled the RT of individual cows in commercial dairy herds to be recorded. The rumination times obtained from the electronic system were highly correlated with those from direct observation, indicating that the electronic system was an accurate tool for monitoring this behaviour in dairy cows (Soriani et al. 2012). Automatic monitoring of intake and rumination showed promise for the detection of health problems after calving. Rumination time can be used to estimate within-cow variation in feeding behaviour and intake, but daily summaries of rumination behaviour are a poor indicator of day in milk (DMI) (Schirmann et al. 2013). According to past investigations, the RT is generally used for the early detection of metabolic diseases such as hypocalcemia, a displaced abomasum and ketosis (Reith and Hoy 2012, Moretti et al. 2017). RT changes during oestrus were determined (Reith and Hoy 2012), but no work has been published on RT changes dependent on the reproductive status of dairy cows.

The aim of this research was to determine rumination time, subsequent milk yield, and trait changes present during lactation, depending on the reproductive status of dairy cows.

Materials and Methods

Location, animals and experimental design

The experiment was carried out on a dairy farm in the east region of Europe at 56 00 N, 24 00 E. Lithuanian Black and White fresh dairy cows were selected according to those fitting a profile of having had a 2nd or more lactations, and being clinically healthy (an average rectal temperature of 38.8°C, rumen motility 5-6 times per 3 min, without signs of mastitis, lameness or metritis). The study was performed on 728 dairy cows from a herd of 1100 cows. The cows were kept in a loose housing system, and were fed total mixed ration (TMR) throughout the year at the same time, balanced according to their physiological needs. Cow feeding took place every day at 06:00 and 18:00. In the present study, the cows under observation were those that had an average of 2.2 ± 1.05 (from first to third) lactations, 161.60 ± 92.99 lactation days, where the average productivity of the cows was 31.49 ± 9.76 kg of milk, and the average time of rumination was 391.91 ± 57.42 min/day.

Measurements

728 cows were selected for 1-150 days of milk (DIM). According to their period of lactation and reproductive status, the cows were classified as belonging to the following groups: Inseminated (1-35 days after insemination (n=182), Open (45-90 days after

Table. 1. Evaluation of investigated traits by the gynecological status of cows.

Period of lactation and gynecological status	Rumination time (min/d)	Milk yield (kg/d)
Inseminated [a]	399.18± 53.41[d]	34.08± 8.34[e]
Open[b]	387.13±69.46	33.57± 11.44[e]
Fresh [c]	397.69± 47.89[d]	34.35±10.06[e]
Not-pregnant [d]	359.60± 83.76[a, c]	32.97± 9.40[e]
Pregnant [e]	390.36±53.59	28.72 ±9.07[a, b, c, d]

Explanations: a, b, c, d – means with different superscript letters differ significantly at $p \leq 0.001$.

Table 2. Dependence of rumination time on the milk productivity in cows of different gynecological status.

Period of lactation and gynecological status	Linear regression equation	R^2
Inseminated	y = 34.074x + 253.44	0.7245
Open	y = 47.856x + 185.33	0.7441
Fresh	y = 16.44x + 329.86	0.8134
Not-pregnant	y = 32.4x + 227.79	0.3998
Pregnant	y = 32.712x + 252.32	0.6474

calving (n=126), Fresh (1-44 days after calving (n=45), Not-pregnant (>35-60 days after insemination and not-pregnant (n=55), Pregnant (35-60 days after insemination and pregnant (n=320). The cows were milked with Lely Astronaut® A3 milking robots with free traffic. To motivate the cows to visit the robot, 2 kg/day of concentrates were fed to them by the milking robot. The rations were calculated according to physiological standards. Daily milk yield, rumination time, bodyweight, milk composition (fat, protein, lactose, somatic cell count) and gynecological status data were collected from the Lely T4C management program for analysis.

Data analysis and statistics

Data were analysed using the SPSS application (Statistical Package for the Social Sciences, 20.0). The findings were provided as average values with standard deviation. To define the relationship between the investigated traits, Pearson correlation, $\chi 2$ test and linear regression equations were evaluated, along with a T-test to define the statistical differences between two groups. The results were considered statistically significant when $p \leq 0.05$. The data obtained from the cows were evaluated by using a linear model: $Y_{ijkl}=\mu + G_i + P_j + R_k + GP_{ij} + GR_{ik} + PR_{jk} + GPR_{ijk} + e_{ijkl}$ where: Y_{ijk}=dependent variable (drumination time); μ=general mean, G_i - gynecological status (five classes), P_{ij} - milk yield of cows (six classes), R_k- milk fat and protein ratio (three classes), PG_{ij} - effect of milk yield x gynecological status interaction, GR_{ik} - effect of gynecological status x milk fat and protein ratio interaction, PR_{jk}- effect of milk yield x milk fat and protein ratio interaction, GPR_{ijk} - effect of gynecological status x milk yield x milk fat and protein ratio interaction, e_{ijk} - residual error.

Results

We estimated the lowest productivity in the pregnant cows, where the average milk yield was 28.72 kg, and the highest productivity in the fresh cow ($p<0.001$) (Table 1). The longest RT was observed in the inseminated cows, and significantly statistically longer by 9.92% ($p<0.001$) than that found in the non-pregnant cows, whose RT was the shortest. The RT of the cows classified as belonging to the status open and inseminated cow groups was similar (Table 1). Analysis showed that the lactation did not have a statistically significant effect on RT ($r=0.075$, $p>0.05$). The RT statistically and reliably correlated positively with the productivity ($r=0.384$, $p<0.001$) of the cows (from $r=0.302$ in the second lactation and $r=0.471$ in the first lactation to $r=0.561$ in multiparous cows; $p<0.001$). Mixing these groups causes stress to the animals, and this status affects their rumination negatively. Figure 1 shows that the RT, according to the groups of cows by their milk yield, showed a tendency to increase (2.14 times) from 202.0± 87.38 min/d (in cows with a productivity of less than 10 kg of milk) to 431.6±33.91 min/day (in

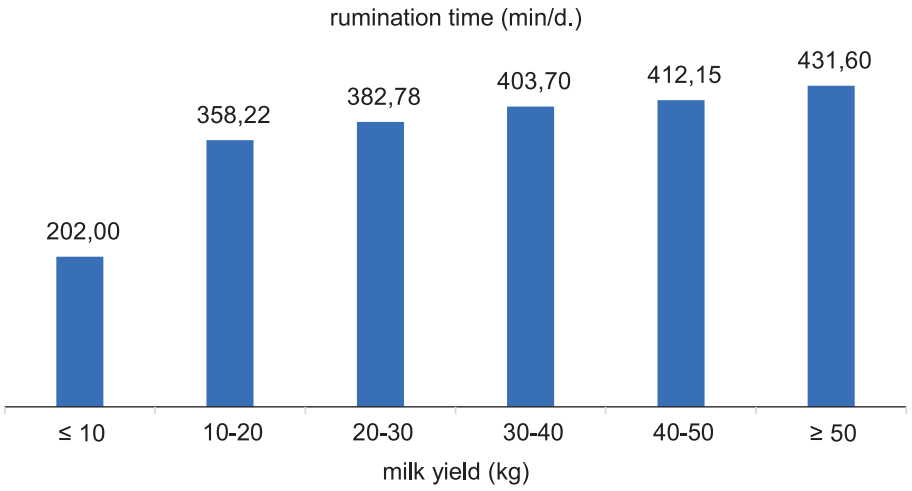

Fig. 1. Rumination time according to the milk yield of cows.

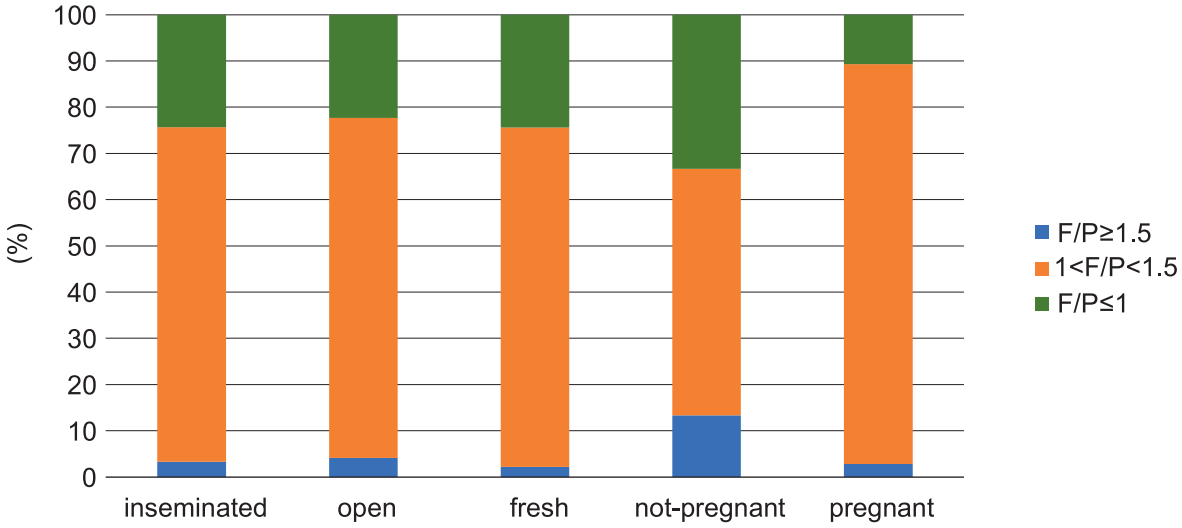

Fig. 2. Relation between the period of lactation and reproductive status and milk fat and protein ratio of cows.

cows with a milk yield higher by 50 kg), as demonstrated by the linear regression equation: y = 38.02x + 232, R^2 = 0.721 (p<0.001). With the increasing productivity of all the groups (according to gynecological status), the RT increases by the linear regression equations (shown in Table 2) with a high R^2 (from 0.66474 to 0.8134) present in the regression model. The estimated R^2 in the not-pregnant cow group was from 1.62 to 2.03 times lower.

The average milk fat and protein ratio (F/P) of the investigated cows was estimated to be 1.147±0.186. The relation between the gynecological status and F/P of the cows was statistically significant ($\chi 2$=2.974, df= 8, p <0.0001). According to our investigation (Fig. 2), the non-pregnant cow group exhibited the highest number of cows with the lowest (≤ 1) F/P level (1.36 - 3.11 times more cows compared to the other groups) and with the highest (≥ 1.5) F/P level (3.17 - 6.50 times more cows).

The RT in cows with an F/P≥1.5 was the lowest (349.57±92.91 min/d), and in the group with an F/P≤1, the longest (402.25±68.41 min/d) (p<0.01). The average RT (391.21±51.61 min/d) was estimated for the group of cows having an F/P of 1 to 1.5. Our analysis showed that the rumination time in cows with an F/P≥ 1.5 was 10.49 % less, and in a group with an F/P≤ 1, 2.81% more (p<0.05) as compared to the group of cows with an F/P of 1 to 1.5 (p<0.01). In the non-pregnant group, 1.36 to 6.50 more cows with levels of F/P ≤ 1 and F/P ≥ 1.5 were determined than in the other groups, according to gynecological status. Analysis of the linear model showed that the RT significantly and statistically depended on the milk yield (Pj, p=0.0001) and gynecological status (Gi, p=0.002) of the cows and on interactions between the milk yield x milk fat and protein ratio (PRjk, p=0.001), gyneco-

logical status x milk yield (GPij, p=0.006) and gynecological status x milk fat and protein ratio (GRik, p=0.006).

Discussion

In the present study we estimated the lowest productivity in the pregnant cows and the highest productivity in the fresh cows. According to Roche (2003), the energy requirements of the fetus throughout pregnancy estimate the effect of pregnancy on milk production and pregnancy-related reductions in yields of milk, milk fat, and milk protein that occurred after mid-gestation, the overall effects of pregnancy on milk production in this pasture-based, seasonal calving system were small.

According our study, the longest RT was determined for the inseminated cows and the shortest for the not-pregnant cows. A decrease in the rumination has been reported to be indicative of stress (Anderson and Muir 2005, Bristow and Holmes 2007), disease (Collier et al. 1982), and pain (Anderson and Muir 2005). According Rodenburg (2011) RT decrease about 10 min per day on the last 5 days before the calving. Moreover, the same author observed a decrease in RT during the day of calving from 220 to 350 min/d. Rumination on the day of calving was less than one-half of the typical time for a dry cow. Soriani et al. (2012) found a variable reduction in RT during the last week of pregnancy, and conversely, a strong reduction in the RT was observed the day before calving in almost all cows. Schirmann et al. (2011) observed a reduction in RT after regrouping, reaching the lowest values on the day of regrouping for cows that stayed in the home pen, and during the day after regrouping for cows moved to another pen, and this was usually observed in heifers that were moved into the lactating group. Thus, heifers undergoing their first lactation require careful management when being introduced to new herd mates and milking facilities. These cows, when compared with pluriparous cows, showed a slower increase in their RT after calving, mainly as a consequence of a decreased RT during milking, suggesting a slow adaptation to the milking procedures (Soriani et al. 2012).

Rumination time statistically and reliably correlated positively with the productivity of the cows. Greater milk production requires greater feed intake, which may result in longer RT than that for low-yielding cows (Stone et al. 2017). Rumination time was shown to have a positive association with milk production in early lactation dairy cows (Asselstine et al. 2016). Rumination time was positively associated with milk yield in early-lactation dairy cows, across all lactations, and negatively associated with the milk fat content in ≥third-lactation cows (Kaufman et al. 2017). It was negatively related to the breathing rate and positively related to the milk yield (Soriani et al. 2012).

Rumination time depended on the milk yield and gynecological status of the cows and on interactions between the milk yield x milk fat and protein ratio, gynecological status x milk yield and gynecological status x milk fat and protein ratio. The low milk fat cows had lower basal concentrations of insulin and lower insulin responses to a glucose challenge (Murphy et al. 2000). Buttchereit et al. (2011) have concluded that F/P is an adequate indicator for energy balance during the energy deficit phase. It can be that non-pregnant cows suffer from subclinical metabolic diseases and that was the reason that they are non-pregnant. Čejna and Chládek (2005) found that an F/P >1.5 suggests a great energy deficiency and subclinical ketosis. A milk fat to protein ratio of <1.15 has been suggested to be an indicator of ruminal acidosis (Ragfar 2007). According to Soriani et al. (2012), the relationships between RT, metabolic conditions, and health status support the automatic measurement of the RT as a useful tool for herd management, and in particular, it could help a farmer to identify animals with a greater probability of having health disorders.

In conclusion, the longest RT was determined for the inseminated cows (1–35 days after insemination), and the shortest for the non-pregnant cows (>35-60 days after insemination and non-pregnant). Rumination time statistically and reliably correlated positively with the productivity of the cows. The dependence of the RT on milk production was 1.62 - 2.03 times lower in the non-pregnant cows. Based on this we can conclude that RT, subsequent yield and milk trait changes depend on the period of lactation and reproductive status of the dairy cow.

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