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Feeding characteristics and rumination time of dairy cows around estrus

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ABSTRACT

Against the background of decreasing reproduction efficiency, estrus detection is gaining increased importance. The objective of this study was to evaluate changes of feeding characteristics and rumination time in dairy cows in the days around estrus. Feeding characteristics were recorded by weighing troughs, and rumination time by acoustic sensors. Analysis included data from 25 primiparous and 37 multiparous cows, which were successfully inseminated (day of insemination = d 0). Feeding time and rumination time were decreased on d −1 and 0, feed intake, and feeding rate on d 0. Primiparous and multiparous cows differed in their reference values, but their feeding and rumination times on the day of insemination were reduced to similar extents. Rumination time was reduced in a time frame of 30 h around estrus whereby the main drop was found during the time period between 0600 h on d −1 and 1200 h on d 0. The change of almost all evaluated feeding characteristics and rumination time around estrus indicated their potential for useful addition in early detection of estrus.
Key words: feeding, rumination, estrus, sensor

INTRODUCTION

Efficient reproduction management has an immediate effect on milk production (Diskin and Sreenan, 2000). Despite all progress in reproduction management, the detection of cows suitable for insemination is still regarded as an essential problem in dairy farming (Roelofs et al., 2010). Consequently, reliable automatic monitoring of estrus in dairy cows is needed. The traditional and mostly used method of detecting cows in estrus is direct observation by the farm staff (Palmer et al., 2010). The efficiency of estrus detection based on observation varies from below 50% up to 90% (Roelofs et al., 2010). In the past, several devices for automation of estrus detection have been developed to face decreased observation time per cow in growing dairy herds (Firk et al., 2002). The combination of 2 or more physiological parameters led to improvement in detection rates (Brehme et al., 2008) and is expected to reduce error rates (Firk et al., 2002). As stated by Firk et al. (2002), it is essential for practical implementation of parameters that these are easily and continuously recordable.

The behavior of dairy cows during the stage of estrus is characterized by specific features. Standing to be mounted by fellows (Hurnik et al., 1975) is often considered as most meaningful factor for estrus detection (De Silva et al., 1981; Van Eerdenburg et al., 1996; Palmer et al., 2010). Further behavioral features characterizing estrus are, for example, restlessness, sniffing the vulva of another cow, flehmen, licking or resting with the chin on the back of another cow (Van Eerdenburg et al., 1996; Sveberg et al., 2011). The altered behavior patterns of cows during estrus indicate an increased physiological activity as an expression of searching for a compatible mating partner (Kerbrat and Disenhaus, 2004).

In addition to the above named alterations in behavior patterns, estrus is accompanied by alterations in feeding and rumination. The effects of estrus on feeding behavior vary in different studies: Lukas et al. (2008) described an increased DMI during estrus, Maltz et al. (1997) and Reith et al. (2014) found a decrease in DMI, and De Silva et al. (1981) found no effect on DMI. In addition, a decrease in rumination time during estrus was described by Reith and Hoy (2012). Feeding and rumination have been investigated separately in former studies, whereas the current study evaluated feeding behavior and rumination time during estrus simultaneously, and thereby helps to deepen the knowledge about temporal concordance of the 2 behavior patterns. The objective of the current study was to evaluate feeding characteristics and rumination time of dairy cows in the days and hours around estrus.

MATERIALS AND METHODS

Animals, Housing, and Feeding

The study was conducted at the federal state research farm LVZ Futterkamp (chamber of agriculture,

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Schleswig-Holstein, Germany). The farm milked around 190 German Holstein cows with an average herd yield of 10,700 kg of milk/305 d (3.9% milk fat and 3.2% milk protein) during the trial period. Data on feeding and rumination were gained from 4 separately conducted trials which were scheduled between August 2010 and August 2011. Only data from cows confirmed to be pregnant after insemination (n = 62) were included in the analysis. According to their lactation number, the animals were classified as primiparous (first lactation; n = 25) or multiparous (≥second lactation; n = 37) cows. On average, cows had been milked for 2.2 lactations. Furthermore, animals were grouped into lactation stage 1 (≤100 DIM; n = 15), 2 (101 to 200 DIM; n = 33), and 3 (≥201 DIM; n = 14).

Cows were kept in 2 pens of a freestall barn on concrete solid floor, which was cleaned by folding slides. Each of the 2 pens held space for 36 cows by providing 36 cubicles, 18 weighing troughs, and 2 water troughs. Overcrowding of pens did not occur during trials. The core of both groups remained stable, and only a small number of cows were taken into or out of the groups according to stage of lactation. At the beginning of each of the 4 separate trials, the groups were reassembled and feed composition was adapted.

Water and TMR were provided ad libitum. Compounds of TMR were corn silage, grass silage, concentrate, straw, and additives. The composition of TMR was calculated to meet requirements of cows with a daily milk yield between 32 and 34 kg. Fresh TMR was supplied 2 times per day at 0600 and 1600 h. No additional concentrate was fed. Cows were milked in a milking parlor between 0500 and 0700 h in the morning and between 1500 and 1700 h in the afternoon. Cow individual milk yield was measured with electronic milk meters (MM25, DeLaval, Glinde, Germany) at each milking.

Weighing Troughs

The 2 research pens of the freestall barn, in which cows were housed during the trial, were equipped with in total 36 feed weighing troughs and 4 water weighing troughs (both Insentec, Marknesse, the Netherlands), that is, one feeding place per 2 cows. The troughs were locked when no cow was feeding, opened after identifying the entering cow via transponder, and closed after the cow had left. The system recorded visit duration and feed intake for each bunk visit of each cow and stored the summed data in units of 24 h. Feeding time was assumed to be equal to visit duration (i.e., comprises times when cows were present at weighing troughs without measurable feeding activity). Feeding rate was calculated as quotient from daily sums of feed intake and feeding time. The daily feeding time and number of feed bunk visits per day were used to calculate an average duration per feed bunk visit per day.

Rumination Sensors

The sensors used for monitoring of rumination were HR-Tags (SCR Engineers Ltd., Netanya, Israel). They consisted of a microphone for sound detection, a microprocessor for data processing, and a transponder for data transfer. Sensors were positioned on a collar behind the left jaw of the cow to identify characteristic sounds of regurgitation and rumination. Rumination time per 2-h periods was calculated internally by algorithms of the system based on raw data. For the analysis in the current study, rumination time per 2 h and per 24 h was considered. Data transfer was conducted by infrared technology. In the current study, readers were placed above water troughs to ensure regular readout.

Artificial Insemination

Cows in estrus were identified by visual observation of herd staff or by physical activity (Alpro, DeLaval, Glinde, Germany). Cows were considered as being in estrus when standing while mounted by other cows. Both systems were used complementary at the same time. Cows in first lactation were inseminated after a waiting period of 75 DIM, multiparous cows from 45th DIM on forward. Artificial inseminations were conducted twice a day, after milking times, by a freelancing veterinarian. Cows were separated into a treatment box directly after milking and regrouped to the herd after insemination. Approximately 40 d after insemination, cows were diagnosed for pregnancy via ultrasound. Only cows inseminated successfully were taken into consideration for analysis. The day of insemination was declared as d 0. On average, cows had been 155 DIM on d 0. Among the 62 cows included in the present study, 46% were inseminated once and 54% 2 times or more for conception.

Statistical Analysis

Daily mean values from d −7 to −3 before insemination and from d +3 to +7 after insemination were averaged, resulting in one individual day of reference per cow for all feeding and rumination variables. The individual reference values were then compared with each of the 5 d around the day of insemination (d −2, −1, 0, +1, +2). Feeding characteristics were calculated in 24 h-periods, and those of rumination time in 24-h periods

and in 2-h periods. Rumination data were excluded from the evaluation when comprising more than one 2-h period within 24 h during which rumination activity was zero. Cows were completely excluded from the analysis when more than half of the days for calculation of the reference day or more than one day between d −2 and +2 were missing. The 2-h periods of the reference day were calculated as average values of the concerning 2-h periods from d −7 to d −3 before insemination and from d +3 to d +7 after insemination. The 2-h periods of the reference day were compared with those of d −2, d −1, d 0, d +1, and d +2.

The program used for statistical analysis was PASW 18.0 (SPSS/IBM; IBM Corp., Armonk, NY). Normal distribution of variables was checked by Kolmogorov-Smirnov test. A linear mixed model was used to analyze the effects on milk yield, feeding characteristics and rumination time. Lactation group (primiparous and multiparous), lactation stage, day, and hour were included as fixed effects. Trial number and cow number served as random effects. No covariates were used in the model. The presence of an interaction between stage of lactation and number of lactation was analyzed by univariate variance analysis. Mean values during the day of reference were compared with the daily mean values of the 5 d around insemination by Bonferroni method. The comparison of 2-h periods of the reference day with those of the days around insemination was conducted by Wilcoxon signed rank test for paired variables. Each 2-h period of the reference day was compared with the corresponding 2-h period of d −2, −1, 0, +1, and +2. Pairs were defined by cow number. The level of significance was $P < 0.05$ for all tests.

RESULTS

The average daily milk yield numbered 35.2 ± 2.0 kg. Multiparous cows (36.8 ± 2.2 kg/d) yielded more milk than primiparous cows (33.2 ± 2.2 kg/d; $P = 0.029$). Daily milk yield did not change according to day around insemination.

Feeding Characteristics

Mean daily feeding time of cows during the reference day was 245 min with a SE of 8.4 min (Table 1). On average, the cows visited the feed bunks 70 times and consumed 20.0 kg of DM during the reference day. Lactation number had a considerable influence on feed intake, feed bunk visits, feeding time, and feeding rate. In general, primiparous cows fed longer per day (primiparous 250 ± 5 min/d; multiparous 206 ± 4 min/d; $P < 0.01$) and visited feed bunks more often (primiparous 75 ± 3 feed bunk visits/d; multiparous 59 ± 3 feed bunk visits/d; $P < 0.01$) than multiparous cows but consumed less TMR (primiparous 18.2 ± 0.3 kg/d; multiparous 20.5 ± 0.2 kg/d; $P < 0.01$). Reference values of both duration per feed bunk visit (primiparous 3.5 ± 0.25 min/visit; multiparous 3.8 ± 0.26 min/visit; $P = 0.30$) and feeding rate (primiparous 81 ± 4 g/min; multiparous 118 ± 6 g/min; $P < 0.01$) were higher for multiparous cows than for primiparous cows. Feed intake in the second lactation stage (19.8 ± 0.247 kg/d) and in the third lactation stage (19.8 ± 0.359 kg/d) was higher than in the first lactation stage (18.4 ± 0.418; $P = 0.049$); feeding rate (0.106 ± 0.005 kg/min; $P = 0.020$) was highest in the third lactation stage. No other analyzed feeding characteristics differed according to stage of lactation. No interaction between stage of lactation and number of lactation on any of the analyzed feeding variables was found.

Feed intake was lower on the day of insemination, and feeding time was lower on d −1 and on the day of insemination when compared with the reference day (Table 1). The extent to which feed intake and feeding time were lower on the day of insemination did not differ between primiparous (1.4 kg and 62 min, respectively) and multiparous cows (2.4 kg and 52 min, respectively). Feeding rate was higher on d 0 (Table 1). The average duration per feed bunk visit lasted 3.7 min (SE: 0.32 min) on the reference day.

Rumination Time

24-h Periods. On the reference day, the mean daily rumination time of cows (d −7 to −3 and d +3 to +7) was 389 min with a standard error of 18 min (Table 1). Cows in the third lactation stage (410 ± 15 min/d; $P < 0.01$) ruminated longer than cows of lactation stage one (333 ± 17 min/d) and lactation stage 2 (340 ± 10 min/d). Individual rumination time per cow per day varied between 127 and 622 min. The difference between average rumination time of primiparous cows (293 min, SE: 12 min) and multiparous cows (430 min, SE: 10 min) was significant on the reference day ($P < 0.01$). The difference between both groups was consistent throughout all days around insemination.

A significant reduction in rumination time was detected on d −1 ($P = 0.037$) and d 0 ($P = 0.044$, Table 1). Rumination time was about 77 min (d −1, primiparous cows: 68 min, multiparous cows: 80 min) and 75 min (d 0, primiparous cows: 74 min, multiparous cows: 76 min) lower than on the reference day. The extent to which rumination time decreased did not differ among primiparous and multiparous cows. Primiparous cows reached the lowest rumination time around estrus on

Table 1. Mean daily values and standard error of rumination time and feeding characteristics per cow during the reference day[1] and the days around insemination

	Reference day	Day around AI				
		−2	−1	0	+1	+2
Rumination time (min)	$389^{a} \pm 18$	$381^{a} \pm 19$	$312^{b} \pm 18$	$314^{b} \pm 18$	$381^{a} \pm 18$	$389^{a} \pm 18$
Feed intake (kg of DM)	$20.0^{a} \pm 0.44$	$20.0^{a} \pm 0.46$	$19.2^{a} \pm 0.45$	$17.5^{b} \pm 0.45$	$19.5^{a} \pm 0.45$	$19.9^{a} \pm 0.45$
Feeding time (min)	$245^{a} \pm 8.4$	$249^{a} \pm 7.6$	$213^{b} \pm 7.4$	$187^{b} \pm 7.4$	$232^{a} \pm 7.5$	$242^{a} \pm 7.5$
Feeding rate (kg/min)	$0.094^{a} \pm 0.006$	$0.093^{a} \pm 0.005$	$0.106^{ab} \pm 0.005$	$0.110^{b} \pm 0.005$	$0.098^{ab} \pm 0.005$	0.095 ± 0.005
Duration feed bunk visit (min)	$3.7^{a} \pm 0.32$	$3.8^{a} \pm 0.30$	$3.2^{a} \pm 0.29$	$3.1^{a} \pm 0.31$	$4.1^{a} \pm 0.31$	$3.9^{a} \pm 0.30$

[a,b]Means within a row with different superscripts differ ($P < 0.05$).

[1]Reference day: mean value of d −7 to −3 before insemination and d +3 to +7 after insemination.

d 0, multiparous cows on d −1. Rumination time of primiparous and multiparous cows returned to the level of the reference day on d +1.

2-h Periods. Rumination time per 2 h averaged between 23.5 min/2-h period (SE: 1.2 min) in the diurnal minimum (1600 to 1800 h) and 48.7 min/2-h period (SE: 2.2 min) in the diurnal maximum (0200 to 0400 h) during the reference day. The peak in daily rumination activity was found between 0000 and 0600 h wherein rumination duration exceeded 43 min/2-h period in each period. A second maximum occurred between 1200 and 1600 h. Phases of low rumination activity were determined from 0600 to 1000 h and from 1600 h until 2000 h and were located after delivery of fresh TMR (0600 and 1600 h). Diurnal patterns were similar for all considered days around insemination (Figure 1).

When 2-h periods of d −2, +1, and +2 were checked against those of the reference day, no significant differences were found. In contrast, on d −1, periods from 0600 h until 0000 h differed significantly ($P < 0.05$) from those of the reference day. Likewise, the periods from 0000 h until 1200 h and from 1400 h until 1600 h on d 0 differed from the corresponding periods of the reference day. This indicates that rumination time was reduced in an overlapping time frame of 30 h, starting from 0600 h on d −1 and lasting until 1200 h on d 0.

Within the day of insemination, rumination time varied between 20.1 min/2-h period (SE: 2.2 min, 0800 to 1000 h) and 35.0 min/2-h period (SE: 2.9 min, 0200 to 0400 h). During the first peak phase (0000 to 0600 h) on d 0, the average rumination time of all cows was reduced by about 12.6 min/2-h period to 13.7 min/2-h period. The accumulated decrease in rumination time between 0000 and 0600 h added up to 40.0 min and was responsible for more than half of the decrease between the day of reference and the day of insemination (75 min). From 0600 to 1600 h, the difference between the 2 d varied from 2.9 min/2-h period to 8.5 min/2-h period.

DISCUSSION

Feeding characteristics can nowadays be recorded continuously and with a high accuracy as proven by validation trials for weighing troughs by Chapinal et al. (2007). The accuracy of rumination time records has been validated positively by Schirmann et al. (2009). Both systems were adequate tools for the current research purposes. Nevertheless, as described by Burfeind et al. (2011), a slight general underestimation of rumination time by the used system cannot be completely excluded.

In the current study, day of insemination instead of estrus was used for data evaluation. As the definite time of estrus was not confirmed by progesterone files, the

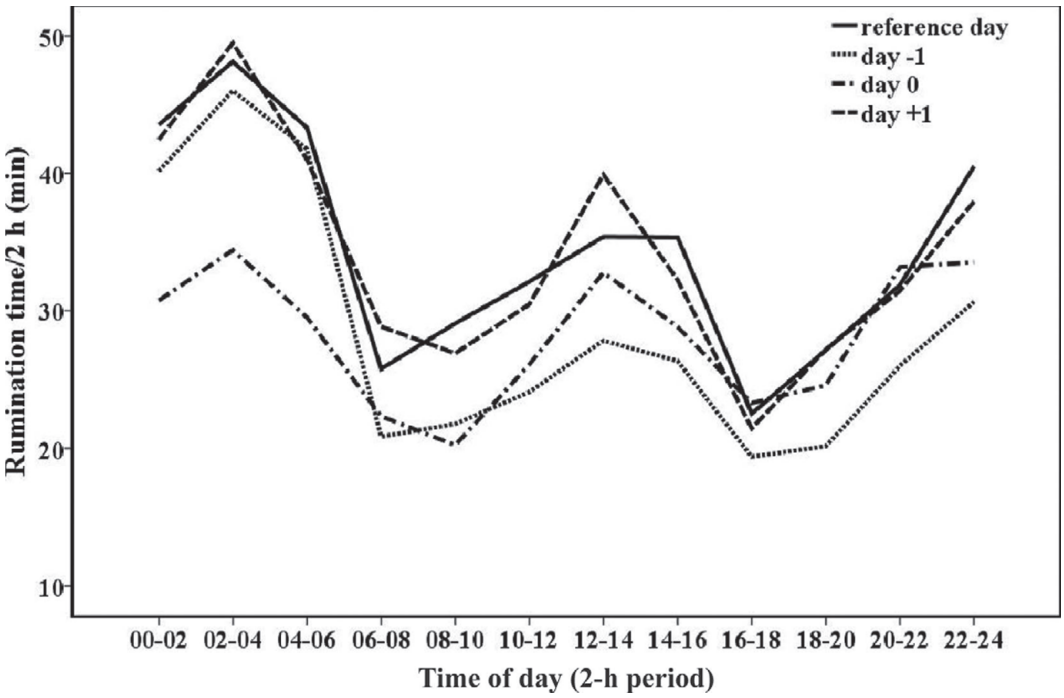

Figure 1. Mean rumination time/2-h period on reference day, d −1, 0, and +1.

evaluated time window comprised in all cases an unknown delay between time of estrus and insemination, a fact that increases primarily the variation in the data and particularly in the point of time at which the start of estrus-related effects on feeding or rumination was observed. However, extensive delays between ovulation and insemination were prevented by studying only cows that were confirmed to be pregnant after insemination. Day of insemination was successful for these cows, and hence changes in rumination and feeding detected on d −1 would be suitable for timely insemination. For practical implementation of estrus detection, it is necessary that, first, systems detect changes in the recorded variables within a suitable time window, second distinguish between estrus and health disorders, and third are complementary to existing methods or systems.

A decrease in feeding time and rumination time was found on the day before insemination and on the day of insemination. Feed intake was lower and feeding rate was higher already on the day before insemination but were reduced significantly only on the day of insemination compared with reference values. The alterations in rumination time and most feeding characteristics were greater between the reference day and the day before insemination than between the day before insemination and the day of insemination, which indicated that most changes would be detectable already on the day before insemination. The decrease in feed intake on the day of insemination in the current study confirmed former findings of Maltz et al. (1997). Changes in feeding behavior go along with increased physical activity and restlessness of cows in estrus (Van Vliet and Van Eerdenburg, 1996), and it is very well conceivable that they are a consequence of increased restlessness during estrus. Arney et al. (1994) found a stepwise increase in activity of cows in the 3 d before estrus. Whereas increase was linear 72 to 16 h before estrus, it was then followed by an accelerated, steep increase lasting until estrus (Arney et al., 1994). In general, an increase in activity of cows is considered responsible for a decrease in resting time and time at feed bunk (Hurnik et al., 1975). Likewise, it might explain the decline in feeding and rumination activity on the day before insemination and the day of insemination in the current study by reducing the available time for feed intake. A temporary decrease in feed intake is accepted for purpose of reproduction. At least in the current study, reduced feed intake and rumination time did not cause a reduced milk yield.

The decline in feeding time from the reference day to the day of insemination in the present study (58 min) was similar to that of cows with acute ketosis (González et al., 2008). Feed intake and feeding rate were reduced dramatically during ketosis (González et al., 2008). In comparison with health disorders, the changes in feeding characteristics around estrus are in general more

short-term. For example, the stage of altered feeding behavior was extended to 3 to 5 d before diagnosis of ketosis and on average 8 d before acute lameness diagnosis (González et al., 2008). Other aspects to distinguish between estrus and health disorders, such as ketosis or lameness, are to consider complementary feeding characteristics, such as feeding/rumination time and feeding rate, or to add information on number and average duration of feed bunk visits. Instead of extending the duration of the reduced number of feed bunk visits on the day of estrus, cows shortened the duration of feed bunk visits and this might suggest an increased level of restlessness.

The decrease in rumination time on the day of insemination was in accordance with results of Reith and Hoy (2012), but the decrease in rumination time started earlier (the day before insemination) in the current study. In total, rumination time was obviously reduced in a wider period around estrus than general indicators such as standing or mounting (Sveberg et al., 2011) or overall behavior (Roelofs et al., 2005). The main time frame of reduced rumination time lasted 30 h in the present study, starting from 0600 h on the day before insemination until 1200 h on the day of insemination. The circadian course of rumination patterns in the days around insemination and on the day of insemination did not change in the present study. Circadian patterns of cow behavior are generally influenced by internal progress of routine farm works (Schirmann et al., 2012). For example, varying amounts of feed intake had no considerable effect on the circadian pattern of rumination activity in sheep (Pearce, 1965). In general, the nighttime from the day before insemination to the day of insemination might be the most promising for detecting behavioral changes in cows. In the time between 2200 and 0400 h, cows usually lie and ruminate to a great amount of time (Schirmann et al., 2012). Cows in estrus showed the highest activity (Diskin and Sreenan, 2000) and the highest mounting frequency (Hurnik et al., 1975) within this time frame. This is in accordance with the obvious reduction in rumination time between 0000 and 0600 h in the current study.

CONCLUSIONS

Rumination time and several feeding characteristics displayed significant changes on the day before and on the day of insemination compared with reference values. The beginning of alterations in the analyzed characteristics on the day before insemination indicated their potential for enhancement of automatic early estrus detection. With regard to rumination time, the most promising time of day for detection of changes was the early morning before insemination. The recorded characteristics add information to current estrus detection methods, such as direct observation or activity measurements.

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