

Automatic monitoring of cow behaviour to assess the effects of variations in feeding delivery frequency

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Abstract

Feeding cows in modern dairy farms is an important economic, animal welfare and technological consideration. The objective of this study was to use electronic monitoring systems to determine the effect of feed delivery frequency on the behavioural patterns and productivity of lactating dairy cows. Ninety three lactating cows were subjected to each of 2 treatments. Feeding treatments consisted of 2 different frequencies (6×/d and 11×/d) replicated in 2 different 7 d periods. Lying behaviour of 8 cows randomly selected was electronically monitored, whereas video recording was used to quantify the feeding time of all cows. All individual-cow milking-related data were automatically collected. Frequency of feed delivery had no effect on daily feeding time, lying time and the lying bouts, but high feed delivery frequency did affect the distribution of the length of the lying bouts throughout the day, decreasing the number of bouts that lasted from 150 to 200 min ($P < 0.01$), and increasing the number of bouts that lasted from 100 to 150 min ($P < 0.05$). Feeding frequency affected the lying time ($P < 0.05$) and feeding time ($P < 0.001$) around the provision of fresh feed. Cows fed 6×/d tended to have a higher milk yield than those fed 11×/d, whereas dry matter intake and utilization of the automatic milking system did not vary by treatment. Based on these results, high feed frequency can be beneficial for even distribution of feeding time through the day, but very high feeding frequencies may disturb the lying behaviour (length of lying bouts) of cows.

Keywords: feeding frequency, behaviour, dairy cow, automatic feeding system, automated monitoring systems

Introduction

Feeding strategies of cows in modern dairy farms are important from both an economic and technologic point of view. The cost and the larger quantity of feeds to be handled for the larger and higher yielding herds, stimulate interest in efficient utilization of feed. The delivery of feed was shown to have the greatest impact in terms of stimulating dairy cows to feed (DeVries and von Keyserlingk, 2005). Delivery of the total mixed ration (TMR) in conventional feeding schedules to lactating dairy cattle for most dairy operations is typically twice per day. However,

many producers elect to feed their cows only once per day to keep the labour cost to a minimum. More recently, automatic feeding systems (AFS) for TMR have been developed, based on either existing technologies or on complete new concepts. The main advantage of AFSs is the possibility to supply a TMR with a high frequency and a low labour input (Belle *et al.*, 2012).

Several studies were aimed at the effect of feeding frequency on the performance, mainly on dry matter intake (DMI) and milk production (Shabi *et al.*, 2005; Phillips and Rind, 2001; Mäntysaari *et al.*, 2006), and on the behaviour of dairy cows (Devries *et al.*, 2005; Hart *et al.*, 2014). The feeding frequency strongly influenced the feeding behaviour (DeVries and von Keyserlingk, 2005; Devries *et al.*, 2005) as well as the lying behaviour (Phillips and Rind, 2001; Mäntysaari *et al.*, 2006). Lying behaviour in free-stall barns is affected by design and management factors, including milking and feeding management (DeVries and von Keyserlingk, 2005; Overton *et al.*, 2002). The range of the feeding frequencies in these studies was between 1× and 5×/day and the cows were milked in a conventional parlour, with a frequency of 2× and 3×/day.

Electronic data loggers are widely available and can be used to effectively analyse cow behavioural patterns), but they require investments in labour, equipment, time and money (Mattachini *et al.*, 2011 and 2013). Video recording systems compared with current data loggers provide a more complete view of all behaviours, in particular for feeding behaviour, and is a valuable tool for investigating dairy cow behavioural patterns (Overton *et al.*, 2002).

The objective of this study was to know what the effect is of high feed delivery frequencies that are possible with AFS on the behavioural patterns and productivity of lactating dairy cows.

Materials and Methods

Animals and housing

The study was conducted between December 2010 and January 2011 at a commercial dairy farm in Friesland (Netherlands), where animals were milked with an AMS (DeLaval VMS, DeLaval International AB, Tumba, Sweden) and fed by an AFS (Mix Feeder, Skiold Mullerup, Ullerslev, Denmark). At the beginning of the study, the barn, housed 93 lactating Holstein-Friesian cows, 21 primiparous and 72 multiparous (parity = 2.7 ± 1.5 , DIM = 138.3 ± 111.5 , milk yield = 31.6 ± 9.7 kg/d; mean \pm SD), and featured a loose-housing layout with a total of 141 cubicles with rubber mats covered with sawdust, and 61 feeding places (0.57 feeding place/cow ratio). The milking area consisted of two AMS units and a closed-in waiting area in front of the unit entrance. One-way gates controlled entrance and exit to the waiting area. The animals had access to the AMS units 24 h/d, except at times for system cleaning (3 times a day at 4:00, 11:00, 20:00). Cows with an interval longer than 12 h since the last milking were fetched, and the minimum time interval between 2 milkings (6-12 h) was a function of milk yield per cow. All cows were fed one mixed ration (MR) (average of 36.3 kg/d per cow) and concentrates were supplied in the

AMS and by two automatic concentrate feeders, placed in the central passage of the lying area. The amount of concentrate (on average 2 kg/d per cow) was a function of the milk production, DIM and parity of the cows. The MR consisted of 70.5% grass silage, 23.3% corn silage, 2.4% rape straw, 3.7% soybean meal and 0.1% mineral and vitamin mix on a DM basis.

Experimental design

Treatments consisted of two different frequencies of MR distributions replicated in 2 periods. Each treatment period lasted 7 d, in which 3 d of an adjustment period (Devries *et al.*, 2005) were followed by 4 d of data collection on the treatment (Ito *et al.*, 2009). The first period started with high frequency treatment (11×/d, the standard practice) followed by low frequency treatment (6×/d), while in the second period the treatments were switched from low to high frequency. The two treatments were 1) 11×/d (at 2:00, 5:00, 7:00, 8:30, 10:30, 12:30, 14:30, 16:30, 18:30, 20:30 and 22:30 h) and 2) 6×/d (at 2:00, 6:00, 10:00, 14:00, 18:00 and 22:00 h). The low feed schedule (6×/d) was defined to create uniform intervals between feedings (4 h) and the quantity of each feed delivery (16.7%), respect the standard practice based on farm feeding management (intervals between feedings from 1.5 to 3.5 h; and quantity of each delivery of 6.7 and 13.4%). In each treatment, feed was pushed up at 13:45, and 15:45 h by the AFS. The AFS assembled the ingredients for the MR and mixed them immediately prior to delivery to the cows by a mixer-feeder wagon. Different types of forage were stored in silage-bunkers, which were filled using a telehandler with front loader once every 2-3 days.

Behavioural data collection

Lying behaviour patterns of 8 lactating cows randomly selected, 2 primiparous and 6 multiparous (parity = 3.4 ± 1.8 , DIM = 188.4 ± 139.5 at the beginning of the data collection period), were automatically recorded using two types of electronic data loggers (HOBO Pendant G Data Loggers and IceTag Activity Sensors). Cows exhibiting health problems were excluded.

HOBO Pendant G Data Loggers (Onset Computer Corporation, Pocasset, MA) were utilized to measure the leg orientation at 1 min intervals and to collect the lying behaviour data electronically (Mattachini *et al.*, 2013). The devices were attached to the lateral side of the right hind leg of the cows by using veterinary bandaging tape (Vet-flex, Kruuse group, Langeskov, Denmark) in a position such that the x-axis of the data logger was perpendicular to the ground. The degree of vertical tilt of the x- and z-axis was used to determine the lying behaviour (Mattachini *et al.*, 2013).

IceTag Activity Sensors (v. 2.004, IceRobotics Ltd., Edinburgh, UK) were used to sample acceleration with a frequency of 8 Hz, and to determine the percentage of time the cows spent lying for each recorded second (Mattachini *et al.*, 2013). IceTag sensors were attached to the lateral side of the right hind leg above the fetlock by means of a strap with a buckle. Lying behaviour was classified for each recorded event based on the IceTag-recorded intensity thresholds (Mattachini *et al.*, 2013).

Data collected by the data loggers were used to calculate lying times (h/d), bout

frequency (n/d) and average bout duration (min/bout) for each treatment. Pre-feeding and post-feeding lying time (min/h) was calculated as the average lying time per cow during the 60 min before and following provision of each fresh feed delivery (feeder wagon starts automatic feed distribution). The length of these 60 min periods was identified in an explorative analysis as the times when behaviour of cows was especially influenced by feed delivery (DeVries and von Keyserlingk, 2005).

Feeding time of the dairy cows was continuously recorded by video recording system for the complete duration of the study. The video recording system consisted of 4 infrared day/night weatherproof varifocal cameras (420SS-EC5, Vigital Technology Ltd., Sheung Wan, Hong Kong) connected to a 4-channel video capture card (Huper Laboratories Co., Ltd., Taipei, Taiwan) in the recording PC. The 4 cameras were attached to beams in the barn approximately 5 m above the pen floor. The feeding time of cows was scored from video using instantaneous scan sampling once every 15 min (Mitlöhner *et al.*, 2001) for 4 d per treatment. For each scan, cows were recorded as feeding when its head was completely past the feeding fence (DeVries *et al.*, 2005). These scans were then used to calculate the daily time spent feeding. The daily feeding time was calculated as the average for 24 h in each treatment day (4 d). Feeding time was also calculated for the 60 min period following the provision of fresh feed (DeVries and von Keyserlingk, 2005). The video analysis was carried out by trained observers with an inter-observer reliability of 98.1% agreement for the behaviour analysed. Reliability was expressed as a Pearson correlation coefficient ($r = 0.96$, $P < 0.001$).

Automatic milking system and milk production

Milking-related data for all cows, including time of entrance to and of exit from the AMS and production per visit, were automatically collected by the AMS and stored as log files. The milking duration was calculated as the difference between the times that a cow entered and exited the AMS. The log files were pre-processed with the support of MS-Excel2007, and the mean milk yield (kg/d), milking frequency (n/d), milking duration (min/m) and refusal frequency (n/d) on per cow basis were calculated for each day.

Feed sampling and analysis

The amount of MR offered was recorded automatically each day by the AFS, whereas the weight of the orts was manually recorded before the first feed delivery of the next day. Representative samples of the MR and orts were taken every day for all 8 d of data collection of each treatment. Dry matter content of the samples was determined by drying at 105°C for 20 h. Dry matter intake for each day of a treatments was recorded by subtracting the DM weight of the orts from the DM weight of the feed delivered by the AFS.

Statistical analysis

Data collected during the study were analysed using SAS (Statistical Analysis System, version 9.2, SAS Institute, 2008). Lying behaviour, milk yield, DMI,

feeding time and AMS utilization were analysed using the GLM procedure of SAS. Least squares means and standard errors were determined using the LSMEANS and STDERR statement in PROC GLM of SAS. In the statistical analyses, significance was declared when $P < 0.05$. A tendency was declared when $P < 0.10$.

Results

Results for the effect of feeding frequency on the lying behaviour of the 8 monitored dairy cows are presented in Table 1. The frequency of feed delivery had no effect on total daily lying time. The feeding frequency did affect the lying time in the hour before and after the provision of fresh feed. Feed delivery 6× compared to 11× significantly increased pre-feeding lying time (32.77 vs. 28.88, min per cow, respectively; $P < 0.03$), and decreased post-feeding lying time (26.85 vs. 30.84, min per cow, respectively; $P < 0.05$). We observed no effect of treatment on the bout frequency and bout duration, but high feed delivery frequency did affect the distribution of the length of the lying bouts throughout the day. Cows fed 11× compared to those fed 6× decreased the number of bouts that lasted from 150 to 200 min ($P < 0.01$), and increasing the number of bouts that lasted from 100 to 150 min ($P < 0.05$).

Table 1: Effect of feeding frequency on lying behaviour of 8 dairy cows randomly selected (least-squares means)

Lying behavior ¹	Treatment		Effect	
	11× ²	6× ²	SE ³	P-value
Lying time (h/d)	12.13	12.25	0.29	0.77
Pre-feeding lying time (min) ⁴	28.88	32.77	1.29	0.03
Post-feeding lying time (min) ⁵	30.84	26.85	1.43	0.05
Bout frequency (n/d)	9.14	9.66	0.46	0.43
Bout duration (min/bout)	88.33	83.51	3.49	0.33
Bout length < 50 min (n/d)	3.06	3.33	0.39	0.68
Bout length 50-100 min (n/d)	2.69	3.31	0.40	0.38
Bout length 100-150 min (n/d)	2.58	2.06	0.08	0.05
Bout length 150-200 min (n/d)	0.56	0.73	0.01	0.01
Bout length > 200 min (n/d)	0.23	0.16	0.06	0.42

¹Data averaged over 8 d for 8 cows randomly selected on each treatment.

²Treatments: 11× = feed delivery 11 times a day; 6× = feed delivery 6 times a day.

³Standard error.

⁴Average lying time per cow during the 60 min before provision of each fresh feed delivery.

⁵Average lying time per cow during the 60 min following provision of each fresh feed delivery.

Table 2 showed the effect of treatment on feeding time, milk yield, DMI and utilization of AMS for all dairy cows during the study. As for lying behaviour, frequency of feed delivery had no effect on daily feeding time.

Table 2: Effect of feeding frequency on feeding time, milk yield, DMI and utilization of AMS (least-squares means)¹

	Treatment		Effect	
	11× ²	6× ²	SE ³	<i>P</i> -value
Daily feeding time (min/d) ⁴	291.6	296.0	4.2	0.48
Post-delivery feeding time (min) ⁵	15.53	21.52	0.67	0.001
DMI (kg/d)	13.43	13.35	0.23	0.82
Milk yield (kg/d)	31.43	32.28	0.29	0.06
Utilization of AMS				
Milking frequency (n/d)	2.86	2.87	0.04	0.85
Milking duration (min/m)	7.46	7.55	0.05	0.20
Refusal frequency (n/d)	2.17	2.04	0.16	0.57

¹Data averaged over 8 d for 93 cows on each treatment.

²Treatments: 11× = feed delivery 11 times a day; 6× = feed delivery 6 times a day.

³Standard error.

⁴Data averaged over 4 d on each treatment.

⁵Average feeding time per cow during the 60 min following feed delivery (4 d).

We did find a significant difference in the feeding time after the provision of fresh feed (Table 2; *P* < 0.001). Cows spent more time feeding during the 60 min following delivery of feed when they were fed 6× (21.5 min per cow) than when they were fed 11× (15.5 min per cow). This difference is shown in the percentage of cows at the feeding fence over the 24 h of the day (Figure 2). When cows were fed 6×, the presence of cows feeding during the period immediately following delivery of fresh feed increased compared with the frequency of 11×. Further, we noted a substantial increase in the number of cows at the feeding fence after the delivery of fresh feed in the morning at 2:00 and 6:00 h, and late evening at 22:00 h when cows were fed 6× compared with when they were fed 11×. For both treatments, the effect of delivery of fresh feed on feeding activity was clear.

Cows fed 6×/d tended to have a higher milk yield than those fed 11×/d (32.3 kg/d and 31.4 kg/d per cow, respectively; *P* < 0.10), whereas there was no difference in DMI when cows were fed 11× compared with when they were fed 6× (13.43 vs. 13.35 kg kg/d per cow, respectively). We found no feeding treatment effect on milking frequency, milking duration and refusal frequency (Table 2).

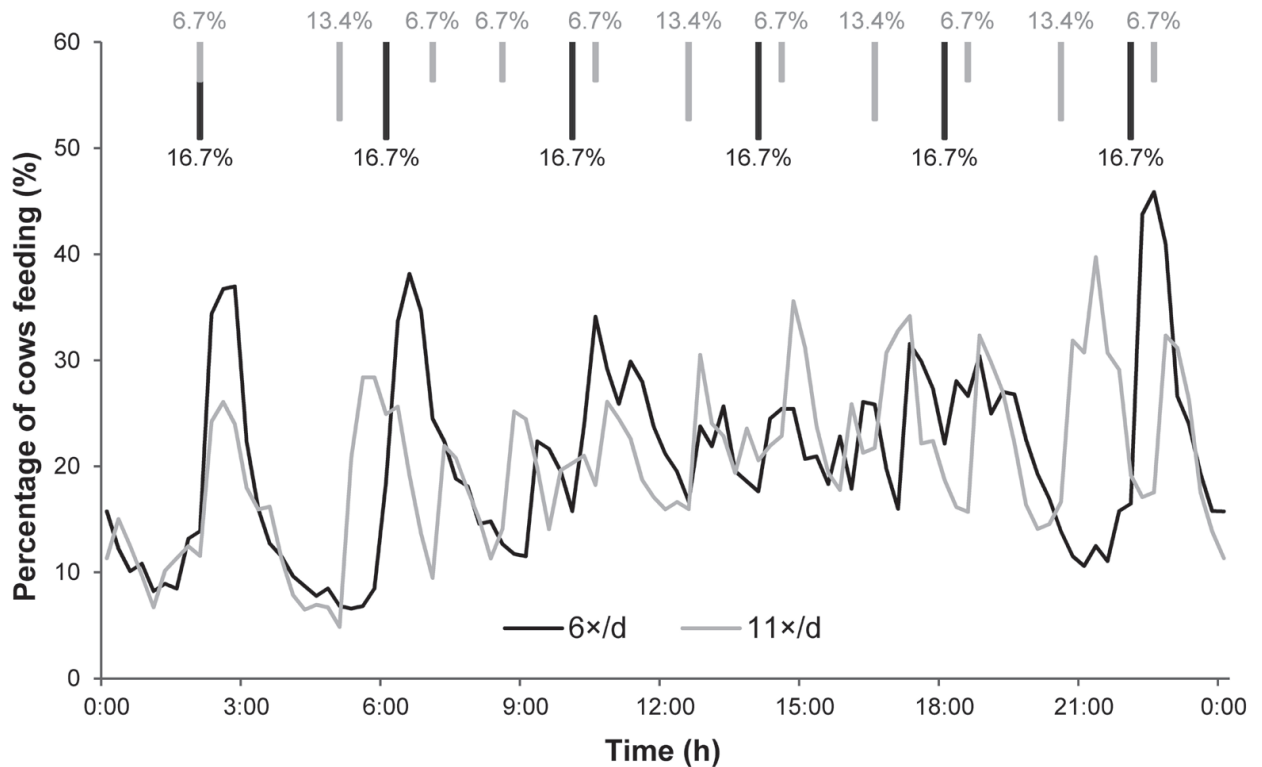


Figure 1: Percentage of cows at the feeding fence over a 24 h period (percentage for each 15 min interval during the day) for the 2 treatments feed delivery 11×/d and 6×/d. Data are averaged for 4 d and 93 cows on each treatment. Solid black and grey bars indicate time of each delivery and quantity (%) of feed delivered at which the cows fed 6× and fed 11×, respectively.

Discussion

Our results correspond with those reported in previous studies (DeVries and von Keyserlingk, 2005; DeVries *et al.*, 2005; Hart *et al.*, 2014), who showed that feed delivery frequency (from 1× to 4×/day) did not affect daily lying time. The present study found no effect of feed delivery frequency also on daily feeding time, which is in agreement with previous work (Phillips and Rind, 2001; Hart *et al.*, 2014). These results contradict with those of DeVries *et al.* (2005) who found that increased feed delivery frequency is associated with increased time spent feeding. This difference in results may be attributed to high differences in frequencies of feed distributions (6× and 11×/day respect to 1× and 4×/day) and milking procedure (AMS respect to conventional milking). However, we observed that the frequency of feed delivery affected the daily distribution of lying time and the lying time during the 60 min before and following the provision of fresh feed, which is consistent with research reported by DeVries *et al.* (2005). Cows fed 6×/d probably tended to spend a longer time feeding, idle or standing on the feeding area after feed delivery. This reflects the fact that when the cows were fed 6×, they increased the time spent feeding during the period following feed delivery as found by DeVries *et al.*, (2005). This could

show that the cows more evenly distributed their feeding time through the day with more spread out of feed intake and reduced competition when feed was delivered at a higher frequency.

In the studies by DeVries and von Keyserlingk (2005) and DeVries *et al.* (2005), the daily distribution of lying time was also influenced by frequency of feed delivery and feeding times. In this study, we observed that the feeding frequency affected the distribution of the length of the lying bouts. The 6× feeding frequency affected the longer lying bouts (100 to 200 min) but not the shorter bouts (< 100 min). The possible explanation may be that cows fed 6×/d are motivated to feed less frequently having more time to lie down continuously between deliveries of fresh feed, as demonstrated to fact that lying has a higher priority over feeding (Munksgaard *et al.*, 2005). Instead, cows fed 11×/d interrupt the longer lying bouts, caused by less time between feed deliveries. In other words, a very high feeding frequency may disturb the length of lying bouts of the cows and thus decrease animal welfare.

Lower feeding frequency had showed a tendency to increase in milk yield, without a variation of DMI. Some studies indicate that milk production was associated with feed intake (Phillips and Rind, 2001), but has also been shown to be correlated with time spent feeding (Shabi *et al.*, 2005). Milk production may be increased by encouraging cows to spend more time feeding (Shabi *et al.*, 2005). Therefore, it is possible that the increase in feeding times after feed delivery and longer lying bout in the present study in response to 6× frequency of feed delivery could translate into a tendency to increase milk production. Feeding frequency had no effect on the utilization of AMS. Our results for the effect of the feeding system on the milkings and refusals frequency are consistent with those of Oostra *et al.* (2005) and Belle *et al.* (2012), who concluded that the feeding frequency had no significant effect on the number of daily milkings and refusals per cow.

Conclusions

Feed delivery frequency affected the distribution of lying bouts and altered the pattern of lying and feeding time throughout the day, affecting mainly the time spent around the provision of fresh feed. Based on these results, high feed frequency can be beneficial for even distribution of feeding time through the day, a more spread out feed intake and reduction of competition, but may disturb the lying behaviour (length of lying bouts) of cows and thus influence animal welfare and milk production.

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