When and where do dairy cows defecate and urinate?

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ABSTRACT

The accumulation of urine and feces can be responsible for many cow and environmental problems. Despite this, little is known about the factors affecting defecation and urination. In the first experiment, the occurrence of defecation and urination behaviors of 48 lactating Holstein cows was observed [days in milk (DIM) = 144.7 ± 38.0 d, body weight (BW) = 667.1 ± 72.0 kg, parity = 2.8 ± 2.3] in freestalls over 48 h. In the second experiment, defecation and urination by 29 lactating Holstein dairy cows were observed (DIM = 62 ± 22.1 d, BW = 590 ± 70.0 kg, parity = 2 ± 1.3) in another freestall barn over a period of 5 d and related to cow activity and feeding behavior. In both experiments, based on total occurrence of eliminative behaviors, cows mainly defecated (experiment 1: $33.4 \pm 2.0\%$; experiment 2: $42.3 \pm 3.1\%$) and urinated (experiment 1: $28.2 \pm 2.5\%$; experiment 2: $42.7 \pm 4.0\%$) in the feed alley and while occupying a stall (defecation: experiment 1: $28.5 \pm 1.0\%$; experiment 2: $26.2 \pm 3.0\%$; urination: experiment 1: $42.2 \pm 1.5\%$; experiment 2: $39.9 \pm 3.8\%$). Occupying a stall included lying, standing in the stall, or standing with 2 feet in the stall and 2 feet in the alley. In both experiments, differences were found between cows in frequency of defecation (experiment 1: 9.8 ± 4.2 /d, range = 3 to 20; experiment 2: 15.4 ± 4.3 /d, range = 6 to 36) and in frequency of urination (experiment 1: 7.0 ± 3.1 /d, range = 2 to 18; experiment 2: 9.3 ± 2.8 /d, range = 3 to 19). Large differences between cows were observed in the frequency of defecation and urination, but these were not correlated with parity, milk production, BW, DIM, or dry matter intake.

Key words: dairy cow, defecation, urination, cleanliness

INTRODUCTION

The accumulation of feces and urine in dairy barns can be related to a variety of problems, such as poor cow hygiene, mastitis, and lameness, which are important concerns for the welfare and productivity of the cows (Warnick et al., 2001; Schreiner and Ruegg, 2003; Zdanowicz et al., 2004). Cow feces can contain infectious bacteria, contribute to the spread of Johne's disease (Stabel, 1998), and pose a risk to human health. The release of volatile ammonia is related to several environmental problems (Moreira and Satter, 2006; Sheppard et al., 2007).

Despite their importance, little is known of the factors that influence defecation or urination by cattle. Most research on defecation and urination behaviors of dairy cows has been done on cows kept in tie-stall barns or on pasture with little research having been done in freestall barns. In tie-stall barns, Aland et al. (2002) found a frequency of defecation of 16/d (range 8 to 29) and a frequency of urination of 9.0/d (range 5 to 18), but little is known of the factors that affect how often cows defecate and urinate.

A better understanding of when and where cows are most likely to defecate or urinate might permit more efficient use of cleaning routines. Aland et al. (2002) found that most defecation occurred during the hours when the animals were most active; that is, during milking and feeding. Some studies have tried to identify the locations where cows were most likely to defecate or urinate. Whistance et al. (2007) found that in freestall housing, cows defecated mostly in the alleys and urinated mainly in the alley behind the stall, whereas in straw yards, cows defecated and urinated slightly more in the bedded area than on the concrete alley. Oudshoorn et al. (2008) found that cows on pasture defecated and urinated more or less equally over their entire grazing surface, suggesting that the amount of feces and urine that accumulate in an area would depend on how much time the cows spent in that area.

The aim of the study was to determine where and when dairy cows in a freestall barn defecate and urinate most frequently, and to relate the frequency of defecation and urination by individual cows to other

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characteristics of those cows such as DIM, parity, BW, and feeding behavior.

MATERIALS AND METHODS

The institutional animal care committees, following the guidelines of the Canadian Council on Animal Care (2009), approved all procedures described in this study.

Experiment 1

Animals and Experimental Area. The 48 lactating Holstein cows were between 34 and 193 DIM (mean $\pm$ SD: 144.7 ± 38.0 d), between first and tenth parity (2.8 ± 2.3), and between 540 and 820 kg of BW (667.1 ± 72.0 kg). Projected 305-d milk production ranged from 7,200 to 16,610 kg ($11,425 \pm 2,223$ kg). Milking was twice daily on a regular schedule, during which time the cows were out of camera view (from 0600 to 0630 h and from 1625 to 1700 h). During the experiment, all cows were fed the same TMR containing, on a DM basis, 18.7% CP and served twice daily on a regular schedule (0700 and 1645 h). All cows were housed in groups of 8 in similar pens in a freestall barn with river-sand bedding and a concrete floor (Figure 1). Stocking density in the pens was 1 cow per lying stall. The pens had 12 lying stalls (stall length = 245 cm; width = 122 cm; neck rail height = 123 cm) and feeder space for 12 cows, but 4 lying stalls and 4 feeding spaces were blocked off. The alley scrapers were set to run 9 times/d in each alley on a regular schedule.

Animals from 6 groups were filmed (3 frames/s) over 2 nonconsecutive days (separated by 1 or 2 d) under normal daily management. Recording dates were between mid August and the end of September depending on the group. In each pen, 2 video cameras (CA Panasonic CCTV Camera, Panasonic, Osaka, Japan) were placed on the ceiling, 1 above the feeder and 1 above the lying stall, to capture the entire pen (Figure 1). To recognize each cow individually, cows were marked with symbols using hair dye at the beginning of the experiment. Red lights (100 W) were used to help recording during the night.

Behavioral Observations. The Omnicast digital system (Genetec Inc., Montreal, QC, Canada) was used to record and view the videos. The videos were read at a speed of 4 times normal speed when 5 or fewer animals were standing in view, but slowed to 2 times normal speed when more than 5 animals were standing in view or when tail activity increased. One observer watched all videos.

The time (to the nearest hour) and location of every instance of defecation and urination was recorded for each cow on each of the 2 d of digital video observations.

Characteristic positions of cows seen during elimination were tail up and evidence of manure (new feces on the floor) for defecation and tail up, round back, and urine appearance (spray of urine on the floor) for urination. When cows were lying down, the tail being stretched out followed by the appearance of new manure at the back edge of the stall or in the scraper alley or a urine flow were evidence of defecation and urination. The location of the cow during defecation and urination was recorded using 6 locations as shown in Figure 1. Cows were recorded as perching when they were standing with the front feet in the stall and the back feet in the alley. If the cow was moving, the location where the first drop of urine or feces fell was recorded. During milking, the cows were out of view. To assess inter- and intraobserver reliability, 3 different observers watched the same 12 h of video and estimated the total frequency of defecation and urination, and 1 observer watched the videos a second time. The total number of eliminative events observed over the 12-h period by one observer was compared with total number of eliminative events observed by another observer and multiplied by 100 to obtain interobserver reliability. Interobserver reliability was 95.5% and intraobserver reliability was 98.0%.

The time of feed delivery and milking time were recorded daily. Cows were weighed before the beginning of recording, and milk production was recorded digitally during each milking (twice daily) using the Dairy Comp 305 program (Valley Agricultural Software, Tulare, CA).

Experiment 2

Animals and Experimental Area. Twenty-nine Holstein dairy cows were housed and observed in a

Figure 1. Pen dimensions, video camera placement, and locations recorded in a pen for experiment 1.

freestall barn in a single pen containing a total of 36 cows. The feeding area was fitted with electronic feed ($n = 18$) and water ($n = 3$) bins (Insentec Inc., Marknesse, the Netherlands), previously validated by Chapinal et al. (2007), that calculate the daily consumption for each cow individually and record the time of feeding and drinking. The alley scrapers were set on manual; therefore, they cleaned the alleys on a random schedule day and night. Stocking density in the pen was 1 cow per lying stall (stall length = 275 cm; width = 125 cm; neck rail height = 123 cm) and 2 cows per feeding bin. Cows were between 8 and 88 DIM on the first day of filming (mean $\pm$ SD; 62 d $\pm$ 22.1), between first and sixth parity (2 $\pm$ 1.3), and between 470 and 760 kg of BW (590 kg $\pm$ 70.0). Corrected 305-d milk production was between 7,510 and 14,930 kg (10,637 $\pm$ 2,032 kg). Milking was twice a day on a regular schedule, during which time the cows were out of camera view (around 0700 to 0800 h and 1700 to 1800 h). During the experiment, all cows were fed a TMR containing, on a DM basis, 17.5% CP and served twice daily on a regular schedule (0600 and 1600 h). For purposes of another experiment, half of these cows were fed a yeast supplement (Celmanax, Vi-cor Varied Industries Corp., Mason City, IA) at 35.5 mL per cow/d. The animals observed for defecation and urination were divided between the TMR diet with ($n = 15$) and without ($n = 14$) yeast supplement. The initial analyses showed that the yeast supplement did not affect eliminative behavior. In the pen of 36 cows, 29 were selected for observation. Those 29 cows had been in the pen for at least 1 wk and were supposed to remain in the pen for at least another week at the beginning of the experiment. Recording dates for those animals were from June 10 to June 15.

The activity of cows (i.e., time spent standing and lying down) was recorded with Hobo G Logger accelerometers (Hobo Pendant G Acceleration Data Logger, Onset Computer Corp., Pocasset, MA), attached on 1 back leg of each cow with vet wrap (Co-Flex, Andover Coated Products Inc., Salisbury, MA).

In the experimental pen, 3 video cameras were placed above the feeding area and 6 above the lying stall area to capture the entire pen (Figure 2). Red lights (100 W) were used for recording during the night. Five complete days (5 $\times$ 24 h) of video data were used. To recognize each cow individually, cows were marked using hair dye at the beginning of the experiment.

Observations. Each instance of defecation and urination was recorded as described in experiment 1. The pen was divided into 6 areas as defined in Figure 2. The location of the cow during defecation and urination was scored using these areas. Each instance of defecation or urination that occurred was recorded within 3 min of the cow standing up. If the cow was moving during the

elimination, the location recorded was where the first drop of elimination fell. The percentage of time spent by the cows in every location of the pen was recorded using a 20-min scan sampling for each day of video analyzed. This was based on previous analyses, which showed that a 10- to 20-min sampling frequency gave a reasonably accurate estimate of total time spent in the main behaviors, with little difference between 10 and 20 min (Haley et al., 2000; Mattachini et al., 2011).

Feeding time and feed and water intake were recorded from the feeding equipment. The milking times were recorded every day. The accelerometer data were used to calculate the mean time per day spent standing and lying down, as well as the frequency of standing bouts for each cow (Table 1).

Cows were weighed on 3 consecutive days at the beginning of the recording, always after the afternoon milking to account for variation of BW due to rumen fill. An average of those 3 weights was used. Body condition score was evaluated the first day of recording using the 5-point scoring system of Ferguson et al. (1994). Milk production was digitally calculated at every milking (twice daily). Cleanliness of the cows was measured once weekly for 5 consecutive weeks using a 3-point scale on the flank, back legs, and udder of the cows, with a higher score (3) indicating a dirtier cow (no published reference available). Average score for every cow over the 5 wk was used for the assessment of correlation.

Statistical Analyses

Statistical analyses were done with SAS software (SAS Institute, 2003). For each cow, the mean frequency of defecation and urination per day was calculated, and the distribution of these data was described using the median, 25th and 75th percentiles, minimum, and maximum. Spearman correlation coefficients were used to analyze the relationship between the mean frequency of defecation and urination per day and average DIM, BW, BCS, daily milk production, 305-d projected milk production, TMR and water intake, time spent standing and eating, and number of standing bouts. In experiment 2, Spearman correlations were used to determine the mean frequency of defecation and urination on each of the 5 d, as well as the correlation between average frequencies over 2 d and over 5 d. In both experiments, the percentage of all instances of defecation and urination that occurred during each hour of the day was examined using graphical assessment.

RESULTS

In both experiments, large differences were found between cows in the frequency of defecation and urina-

Table 1. Distribution of the feed intake, water intake, time spent feeding, frequency of standing bouts, and cleanliness score in experiment 2

Item	Minimum	Mean	Maximum	SE
Feed intake (kg)	17.6	48.5	72.0	10.4
Water intake (L)	40.5	104.4	169.8	26.4
Time spent feeding (min)	138.6	264.2	419.2	49.9
Frequency of standing bouts	4	8.7	15	2.4
Cleanliness score	1.31	1.76	2.32	0.02

tion. Table 2 shows the frequency of defecation and urination observed over a 2-d period for experiment 1 and a 5-d period for experiment 2. Correlations were found between the frequency of defecation and frequency of urination of $r = 0.41$ ($P = 0.004$) in experiment 1 and $r = 0.39$ ($P = 0.04$) in experiment 2. In experiment 2, positive correlations were found across days for the frequency of defecation and for the frequency of urination, although for some days, these were nonsignificant (Table 3). The estimates of the frequency of urination and defecation based on 2 d of observation were correlated with the estimates based on 5 d of observation ($r > 0.85$; $P < 0.001$).

In neither experiment did we find clear evidence of diurnal rhythms in the frequency of defecation and

urination (Figure 3). Although the time spent standing or at the feeder did show rhythms, no close association was observed between these and the occurrence of defecation and urination.

For experiment 2, 12.6% of all instances of defecation and 21.4% of all instances of urination were recorded as happening within 3 min of the cow standing up. In experiment 2, no correlation was found between frequency of defecation ($P = 0.93$) or frequency of urination ($P = 0.45$) and frequency of standing bouts per day.

Figure 4 shows the percentage of all instances of defecation and urination that occurred in each location of the barn. In both experiments, a high frequency of defecation and urination occurred in the lying stall and in the feed alley. Defecation and urination in the lying

Figure 2. Pen dimensions, video camera placement, and description of the 6 areas where elimination occurred for experiment 2.

Table 2. Distribution of the daily frequency of defecation and urination for experiments 1 ($n = 48$ cows) and 2 ($n = 29$ cows)

Daily frequency	Experiment	Minimum	Quartile 1	Median	Quartile 3	Maximum
Defecation	1	3.0	7.00	9.75	12.50	17.5
	2	9.4	12.60	15.39	17.60	22.8
Urination	1	3.0	5.25	7.00	8.50	16.0
	2	6.4	7.60	9.30	10.60	14.6

stall area could occur when the cow was in 3 different positions, lying, standing, or perching. In experiment 1, 4.7% of defecation events and 1.5% of the urination events occurred while the cows were lying down in the stall, 2.3 and 2.1% when the cows were standing with 4 feet in the stall, and 21.5 and 38.6% when perching. In experiment 2, cows defecated 8.2% and urinated 0.1% of time lying down in the stall, 4.6 and 8.8% of time standing with 4 feet in the stall, and 13.5 and 31.0% of time perching.

For experiment 2, the total time spent by the cows in each of the 4 locations was calculated and compared with the frequency of defecation and urination (Figure 5). In Figure 5, the location “stall” included when cows were lying, standing with 4 feet in the stall, or perching. The cows defecated 0.2 times per hour when lying in the stall. When standing with 4 feet in the stall, cows defecated 4.4/h and urinated 8.6/h. In the perching position, the cows defecated 1.3/h and urinated 2.9/h.

For experiment 2, 81.4% of the defecation events and 80.7% of the urination events that occurred while the cow was standing in the stall happened within 3 min of standing up. For the perching position, 37.6% of defecation and 31.7% of urination occurred within 3 min of standing up.

For experiment 1, a significant correlation ($r = 0.37$; $P < 0.01$) was found between frequency of urination and DIM. In experiment 2, the average cleanliness of the cows and the frequency of defecation were not correlated. A trend was observed for the cleanliness of the cow to be positively correlated with the frequency of defecation while lying down ($r = 0.32$; $P = 0.094$).

In experiment 2, cows defecated 8.5% of time lying in their stall, this proportion ranging from 0 to 22.9%. A correlation was observed between time spent feeding and defecation ($r = 0.16$; $P < 0.05$) and between time spent standing and urination ($r = -0.45$; $P < 0.05$).

DISCUSSION

The frequencies of defecation and urination behaviors found supported those reported for cows kept in tie-stall barns and in freestall and straw-pen barns (Aland et al., 2002; Whistance et al., 2007). Large differences were observed between cows in the frequencies of defecation and urination. The frequencies were not correlated to any production or physiological traits such as milk production, DIM, parity, feeding behavior, or BCS.

Variation in the daily frequency of defecation between cows in the experiments ranged from 3 to 18 (experiment 1) and from 9 to 23 (experiment 2), which supports the variation found by Aland et al. (2002) that ranged from 8 to 29. The very low frequencies of defecation found might be because we were not able to observe defecation and urination during milking time. The daily frequency of urination by cows ranged from 2 to 18 and from 3 to 19, for experiments 1 and 2, respectively. Those ranges support Aland et al. (2002; 5 to 18 urination per day) and Suzuki et al. (1967; 2 to 20 urinations per day). The variation in the frequency of defecation and urination was not related to DIM, BW, BCS, daily milk production, activity level, or feed and water intake.

Table 3. Correlations between days for the daily frequency of defecation and urination in experiment 2 (Spearman correlation coefficient P -values)

		Day 1	Day 2	Day 3	Day 4
Day 2	Defecation	0.60***	—	—	—
	Urination	0.70***	—	—	—
Day 3	Defecation	0.72***	0.63***	—	—
	Urination	0.28	0.37*	—	—
Day 4	Defecation	0.52**	0.55**	0.49**	—
	Urination	0.66***	0.49	0.47**	—
Day 5	Defecation	0.49**	0.77***	0.63***	0.54**
	Urination	0.45*	0.49**	0.36	0.38*

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$ ($n = 29$ cows for d 1, 2, 3, 4, and 5).

Figure 3. Percentage of the total frequency of defecation and urination behavior that occurred at each hour of the day for (a) experiment 1, averaged over 2 d, and (b) experiment 2, averaged over 5 d, and the percentage of total daily time spent eating and standing during each hour in experiment 2. During milking time, the cows were out of camera view and so no data were available.

Figure 4. Percentage of all instances of defecation and urination that occurred in each of 4 locations within the dairy barn in (a) experiment 1 and (b) experiment 2.

Some stability was observed from day to day in the differences between cows in the frequency of defecation and urination. The correlations between days ranged from 0.49 to 0.77 for defecation and from 0.28 to 0.70 for urination, suggesting that cows that defecate and urinate more frequently do so regularly. Aland et al. (2002) found no significant differences between different days on the frequency of elimination, whereas an amount of variation was found between days for each cow. Frequency of defecation was more correlated between days than was frequency of urination. Our results suggest that 2 d of recording gave a good estimate of the frequency of defecation and urination occurring in 5 d.

The frequencies of defecation and urination were correlated with each other, supporting Fuller (1928) but not Aland et al. (2002), who did not find a significant correlation between these traits. This correlation may reflect that cows seemingly defecate and then urinate within a short period.

Figure 5. Rate of elimination (frequency/h) based on time spent by the cows in every location in experiment 2 (lying stall: defecation: 5.8 ± 1.2 , urination: 11.5 ± 3.7 ; stall alley: defecation: 4.5 ± 1.0 , urination: 2.4 ± 0.4 ; cross over: defecation: 2.3 ± 1.1 , urination: 1.7 ± 0.9 ; feed alley: defecation: 1.3 ± 0.1 , urination: 1.4 ± 0.1).

Sahara et al. (1990) reported no diurnal pattern in either defecation or urination behaviors, which suggests that no critical period exists when the scraper should be used more to keep the barn clean. Nevertheless, Aland et al. (2002) reported a lower frequency of elimination in tie stalls during the resting time, which, in their experiment, accounted for more than half of the day.

In both experiments, cows defecated more often in the feed alley, whereas urination occurred equally often in the feed alley and in the lying stall. The frequency of defecation and urination did not simply reflect the time the cows spent in each area, as was found by Hirata and Higashiyama (1996) for cows on pasture. The rates of defecation and urination were lowest in the lying stalls and highest in the alley. Relatively little defecation or urination occurred in the crossover area. In experiment 1, the cows defecated and urinated more in the crossover area, but that was where the water trough was located. In experiment 2, the water trough was situated in the feed alley.

Cows urinated and defecated more standing in the stall compared with the percentage of time they spent in that position. Even if the cows did not spend much time standing with 4 feet in the stall, they defecated or urinated in this position and increased the chance of depositing their urine and feces in the stall or on its edge. The high frequency of defecation and urination in this position might be related to the high proportion of cows defecating and urinating in the minutes following the moment they stand up. This behavior is likely to decrease the cleanliness of the stalls and of the udder and rear legs. Cow and stall cleanliness is an important factor for udder health (Schreiner and Ruegg, 2003). A certain proportion of defecation occurred while cows were lying in the stall, which likely increases the dirti-

ness of the cow and the stall. Important variation between cows was observed in defecation while lying. On average, 8.5% of defecation events occurred when cows were lying. Similar to Whistance's (2007) results, in both experiments, over 30% of urination occurred when cows were perching in the stalls. In contrast, Whistance (2007) found that around 25% of defecations were occurring while cows were standing in the stall. In both experiments, less than 5% of defecation occurred in that position. These differences might be due to the stall design and neck rail position (Tucker et al. 2005).

In our second experiment, no correlation was found between the frequency of defecation and urination in each hour of the day and the amount of feeding at that time of the day. The delivery of fresh feed does not seem to affect the defecation and urination of cows in a freestall barn as it does in tie stalls (Aland et al., 2002). For experiment 1, a correlation was found between the frequency of urination and DIM, but this correlation was not found in our second experiment. This difference might be due to the difference between the average DIM and variability in DIM for the cows in each experiment (exp. 1: 145 ± 38 d.; exp. 2: 62 ± 22 d). In addition, this variation might be due to the stage of lactation difference: most of the cows were pregnant in experiment 1, whereas none were pregnant in experiment 2.

CONCLUSIONS

Cows vary in how often they urinate and defecate. The frequency of defecation and urination were not related to or correlated with feeding and standing time or with DIM, 305-d milk production, daily milk production, BW, or TMR and water intake. The occurrence of defecation and urination behaviors was distributed almost equally over the 24-h period of the day, suggesting that it is not advantageous to clean the alleys more often during certain times of the day. The average occurrence of a type of eliminative behavior (defecation or urination) differs between the areas of the pen; some places are overused for urination compared with the time spent in this location.

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