Use of a urine meter to detect variation in urination behaviour of dairy cows on winter crops

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Abstract

Nitrate leaching loss from urine patches is predicted using a number of variables including urine N concentration, number of urine patches produced, and urine patch size however, there is a lack of quantitative data on the variability of urination events. A study was conducted using two wintering systems at Ashley Dene, Lincoln, between June and July 2014. Wintering systems were either kale (KA) fed at an allowance of 14 kg DM/cow/day plus barley straw (3 kg DM/cow/day) (n=5), or fodder beet (FB) fed at an allowance of 8 kg DM/cow/day, plus ryegrass baleage (6 kg DM/cow/day) (n=7). Twelve pregnant, non-lactating Holstein-Friesian x Jersey cows were fitted with calibrated urine meters which measured volume and frequency of urination events. The meters were worn for 24-hour periods. A calibration equation was used to calculate urine patch coverage from measured urine patch areas in the field and urine volumes. There was large variation between animals for urination behaviour. Average urination volume was similar for KA and FB (2.37 L/event; $P>0.1$ SEM=0.29), however urination frequency (12 vs. 8 events/day; $P<0.1$ SEM=2.25) and daily total urine volume (30 vs. 18 litres; $P<0.03$, SEM=4.56) were greater for KA. Average urine patch area was also 1.8 times larger on KA than on FB (0.47 vs. 0.25 m^2). This information will be used to help predict nitrate leaching losses from grazing systems.

Keywords: *Brassica oleracea*; *Beta vulgaris*; urine volume; urine frequency; urine patch area; spatial coverage; nitrogen; leaching

Introduction

Nitrate (NO_3^-) leaching from agricultural soils has been identified as posing major potential threats to groundwater quality in New Zealand (Cameron et al. 2002; 2013). Most NO_3^- leaching from dairy farms occurs due to high concentrations of N in the cow urine. This is because ruminants grazing a pasture diet excrete 75-95% of the N they ingest, the majority being excreted in urine (Eckard et al. 2010; Selbie et al. 2015). Urinary N concentrations in a single urine event represent equivalent N application rates of between 800-1300 kg N/ha (Eckard et al. 2010), and studies have shown that the average leaching loss of N applied in urine patches is 20% (Cameron et al. 2002; Selbie et al. 2015).

Winter is a particularly high risk period for NO_3^- leaching losses because soils are wet and drainage is high. Common wintering practices of grazing dairy cows on brassica crops *in situ* can contribute a disproportionate amount of whole-farm NO_3^- leaching losses representing 11-24% of farm annual N losses, despite representing only 4-9% of the farm system's area (Chrystal et al. 2012). This is because of high stocking densities on winter forage crops, in conjunction with the high drainage, overland flow and lack of plant uptake that occur in winter due to high rainfall and low temperatures.

Regional authorities throughout New Zealand have, or are developing, regional plans to manage water quality, aimed at reducing agricultural NO_3^- and other nutrient levels in surface and ground water (Williams et al. 2013). The favoured approach is to regulate losses from the farm rather than capping nutrient inputs and to calculate N losses using simulation models that use variables such as stock number, grazing area and length of time grazed, number of urine patches produced, urine patch size, and urine N concentration, to predict leaching loss. The models used to make these predictions are only as reliable as the available data and information they are based upon. Currently, information on urination events under field conditions is limited due to the difficulty of continuous monitoring of urination behaviour in dairy cows.

While there is already significant knowledge about ruminant urinary N concentrations and leaching loss percentages from urine depositions there is very little information available about the volume, frequency and distribution of dairy-cow urine deposited during the winter grazing of forage crops. Current knowledge suggests that dairy-cow urination events on grass are highly variable in both volume and frequency, studies with R1 and R2 steers have shown that urination events can vary from 13 to 73 events in 24 hours, and total daily output from 5.8 to 54.7 litres (Betteridge et al. 1986).

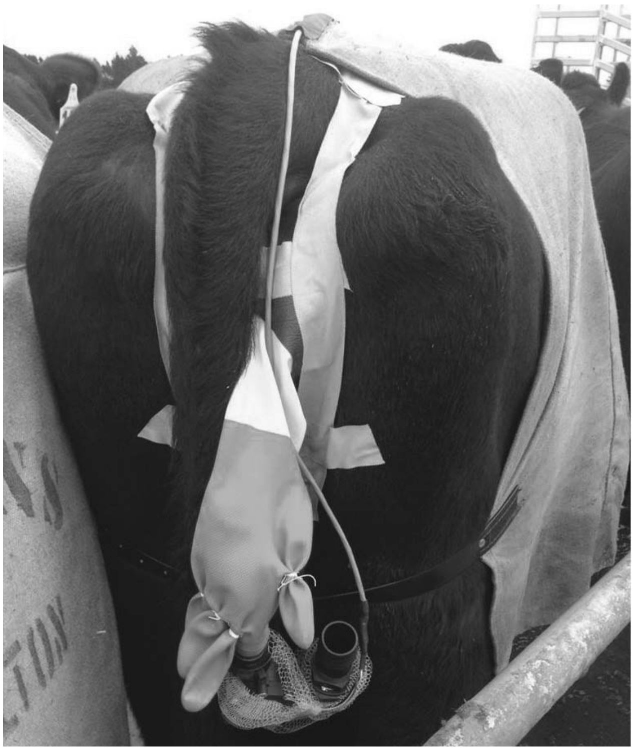
Therefore the purpose of this study was primarily to develop and use a device to quantify the frequency and volume of urination events of dairy cows and secondly to use this information to attempt to determine urine patch coverage under grazing.

Materials and methods

Urine meter

A urine meter was developed which consisted of a flow meter (Sea YF-G1 Water Flow Sensor) connected to a data logger (Campbell Scientific CR211X). A rubber glove was modified to channel all urine through the flow meter. Information was stored in the data logger which was inserted into a pocket on a cow cover. A U-bend was connected to the flow meter outlet to ensure that liquid, rather than air, always surrounded the flow-sensing rotor. The pulse signals from the flow-meter, as liquid passed through, were calibrated in a laboratory using known volumes of water. Stored data was filtered and removed if the event duration was less than four seconds. Previous analysis of data showed that rejection of events of 4 seconds or less was approximately equivalent to filtering out events that resulted in a volume record of <100 mL.

Figure 1 Urine meter on a dairy cow. The modified glove attachment was glued around the vulva and urine was channeled through the flow meter. Strapping tape was used to support the weight of the meter across the flank and pins of the cow and also helped prevent faecal contamination. Information from the flow meter is stored in a data logger which was attached to the cover.



The meter itself was attached to the vulva of the cow by gluing (Henkel's Loctite Power Flex Gel) the modified glove attachment to the exterior skin around the vulva, and using strapping tape to support the weight of the meter across the flank and pins of the cow. The strapping tape also helped to prevent faecal contamination into the meter. The meter weighed around 100 g; initial attempts to transfer its weight to the cow cover failed as they restricted the movement of the glove causing it to kink during urination, slowing the flow of urine through the sensor. Therefore the meter was only attached to the cow's skin (Fig. 1). During the development and testing phase three non-lactating dairy cows were used to assess effectiveness of the device and any potential welfare issues. Cow behaviour was initially altered when the cover was fitted to the animals. Some cows ran or bucked shortly after the cover was fitted, though normal activity (grazing) resumed within 30 minutes.Cows were subsequently given 24 hours to adapt to the cover before the urine meter was attached. Once on the animal, general movement such as standing and sitting resulted in pulse signals from the meter which were not urination events. Any animal where the meter was not firmly affixed to the vulva at time of inspection were recorded and results for that animal were disregarded. While the meter remained firmly affixed to the vulva, no faecal material could contaminate the flow meter.

Grazing experiment

The experiment was conducted using two conventional Canterbury wintering systems, between June and July 2014 at Ashley Dene, situated near Burnham, Canterbury, (-43.65° N, 172.33° E) with the approval of the Lincoln University Animal Ethics Committee (AEC #551). Average daily temperature was 7.6 °C. Experimental details are outlined by Edwards et al. (2014a), briefly, the two winter feeding systems used consisted of kale (KA) fed at an allowance of 14 kg DM/cow/day plus barley straw (3 kg DM/cow/day) or fodder beet (FB) fed at an allowance of 8 kg DM/cow/day, plus ryegrass baleage (6 kg DM/cow/day). Although forage measurements were not carried out, previous results comparing the same systems indicated that diets (crop plus supplement) had similar apparent energy intake (160 MJ ME/cow/day; Edwards et al. 2014a) but greater apparent N intake on kale than fodder beet (280 vs 230 g N/cow/day respectively; Jenkinson et al. 2014).

A total of 50 Friesian x Jersey cows (505 ± 6.1 kg LW) grazed each of the treatments. Supplement was fed to cows daily at 0700 h followed by access to crop at 0800 h and cows always had access to fresh water. Ten animals in each treatment were randomly selected to wear covers for at least 24 hours in advance of meters being attached. Records from urine meters occurred over three runs on the 9th, 14th, and 16th of July 2014, when up to five animals at a time wore the meters for up to 48 hours. Between 1400 and 1600 h assigned cows from each mob were herded into yards and meters were affixed. In the first run, meters remained attached to only two of the cows for the full 24 hours.

Improvements in attaching the meters using more effective strapping tape resulted in six of the 20 animals providing three sets of 24-hour data. Eight animals were either difficult to train or urine meters came unstuck, leaving seven cows from FB and five cows from KA with at least one complete set of readings from the urine meter. Only 24-hour data was used in subsequent analyses.

The relationship between urine volume and urine patch area was determined by measuring the *in situ* wetted area immediately following application of simulated urinations of different volumes. A urination event was simulated by pouring set volumes of water from cow vulva height (~1.2 m) onto the ground in the KA and FB treatment paddocks. Ten simulated volumes were used: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, and 5.0 litres with each volume replicated five times. The outline of the wetted area was marked with spray paint and photographs of each simulated urine patch were analysed using online-based irregular area software – SketchAndCalc™. Simulated urine patch area was plotted against volume applied.

Statistical analysis

Urine volume and frequency data were analysed using one-way ANOVA in Genstat (VSN v16.0) using crop treatment as a fixed effect and cows as replicates. The relationship between urine patch area and urine volume was determined using linear regression. Results were considered significant when P<0.1.

Results

There was large variability among cows in the volume and frequency of urination (Table 1). From the 21 complete sets of measurements over 24 hours, total volume recorded ranged from 8.7 to 47 litres/cow/day. Urine volume per event was also highly variable, averaging 2.4 litres, though several events of less than 1 litre were recorded as well as events which exceeded 5 litres. The largest single event was 8.6 litres, with many of the large events of 4 litres or more occurring between 0600 and 0730 h or between 2200 and 0000 h.

Table 1 Total urine volume and number of urinations of Friesian x Jersey cows grazing a wintering system consisting of either a kale (KA) or fodder beet (FB) crop with standard errors of the mean for cows which have worn the urine meters for two or three days.

Cow rep	Crop	Total Urine Volume (L/24 h)	Frequency of Urinations (# per 24 h)
1	KA	25.4 ± 1.9	11.0 ± 1.0
2	KA	31.1 ± 3.4	8.0 ± 0.7
3	KA	26.6 ± 3.6	11.0 ± 3.0
4	KA	19.2 ± 4.8	10.5 ± 0.5
5	KA	47.3	21.0
1	FB	20.3 ± 4.1	8.3 ± 0.3
2	FB	20.2 ± 6.4	11.0 ± 1.0
3	FB	25.2	10.0
4	FB	15.4	6.0
5	FB	8.7	3.0
6	FB	18.2	10.0
7	FB	17.9	9.0

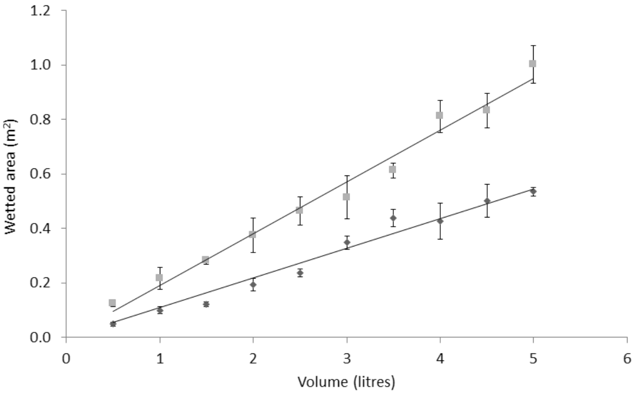
There was little difference between KA and FB in the average volume of an individual urination (2.37 ± 0.29 litres/ event); however frequency of urination over 24 hours tended to be lower on FB (12 vs. 8 events/day ± 2.25, P<0.1) (Table 2). Total daily urine volume was also greater in KA than FB (30 vs. 18 litres ± 4.56 P<0.03) (Table 2). There was no re-ranking of urine variables when values were adjusted for live weight (Table 2).

The relationship between urine volume and urine patch area is depicted in (Fig. 2) where area = 0.109 x volume (R^2 = 0.89) for FB and area = 0.190 x volume (R^2 = 0.89) for KA. The average urine patch area, using the volume data from Table 2 and the relationship between volume and area, estimates a urine patch size of 0.47 m^2 on KA and 0.25 m^2 on FB.

Table 2 Effect of fodder beet (FB) or kale (KA) crop wintering system on the urination behaviour of non-lactating dairy cows.

	FB (n = 7)	KA (n = 5)	SEM	P-value
Number of urinations (/ 24 h)	8.19	12.3	2.25	0.098
Frequency (urinations/h)	0.34	0.51	0.09	0.098
Total urine volume (L/ 24 h)	17.97	29.91	4.56	0.026
Average urination volume (L)	2.31	2.46	0.29	0.607
Urination volume (ml/ kg LW)	4.66	4.98	0.57	0.583
Daily urine volume (ml/ kg LW)	36.17	61.28	10.24	0.034

Figure 2 Calibration curve depicting the relationship between the artificially applied volume of urine and the area of the urine patch produced on the fodder beet (FB (diamond)) and kale (KA (square)) treatments *in situ*. Error bars represent standard error of the mean.



Discussion

Urination behaviour by dairy cows grazing kale or fodder beet was highly variable, in both frequency and volume. The results are similar to previously published data, for example, Aland et al. (2002) found grazed dairy cows urinated on average 9.0 times per day (range 5-18); while Castle et al. (1950) reported a daily urine frequency of 9.8 times. During a grazing study in New Zealand, Draganova et al. (2010) found urination frequency was 0.5 events/hour/cow. These results suggest that while variation in urination frequency exists, the average dairy cow urinates between 7 and 13 times each day.

On average, urination volumes per event were around 2.4 litres with no significant difference between KA and FB. This result is consistent with that of Betteridge et al. (2013) who found average urination volume to be 2.1 litres for cross-bred dairy cows grazing break-fed pasture. Total daily urine volume differed between KA and FB. Cows on KA system produced an average of 30 litres/day, while cows on the FB system only produced 18 litres/day. The small number of animals used in this study makes it difficult to conclude whether feeding diet treatments such as fodder beet or kale could significantly alter urine volumes. Water ingestion through drinking troughs and feeds will affect water balance, as will mineral intake. Studies have shown that nitrogen ingested in forages and concentrates to be the principal factor affecting the volume of urine; animals fed high protein diets consume more water, and excrete more urine than animals on lower protein diets (Bannink et al. 1999; Khelil-Arfa et al. 2012). While the purpose of this study was to develop a tool which would enable measurement of urination volume and frequency, future use of this tool will coincide with additional measurements which will allow greater exploration of factors governing urine behaviour.

To estimate the risk of N being leached from urine patches, information is required on the interaction between the volumes of urine deposited, the concentration of N in the urine and the area over which it is deposited on the soil. The current results showed that urine patch area was larger for KA (0.47 m^2) than FB (0.25 m^2). There are a large number of variables which determine infiltration into the soil and thus the area of soil affected by each urination, including soil surface microtopography, moisture content, vegetation cover, slope, wind and the presence of pores open to the soil surface (Williams & Haynes. 1994). It is likely that these factors are the reasons driving the results obtained in this trial, in particular the differences in the soil surface microtopography. The depression left after removal of the fodder beet bulb appeared to lead to the capture of urine into a smaller area as urine pooled in the depression. In contrast, kale is grazed above ground and the soil surface remains relatively flat after grazing, so urine is able to spread out wider across the soil surface.

Smaller urine patch areas on the FB treatment compared to KA (0.25 vs. 0.47 m^2) could lead to a greater N load, though more information on N concentration is required to accurately assess N loading from urine events. In related work in the same forages, Edwards et al. (2014b) reported a similar urine N concentration for cows grazing fodder beet (2.1 g N/L) and early sown kale (2.3 g N/L) crops. Further improvement of the urine meter might be to incorporate technology which would enable measurement of N concentration of urine events. However, based on information on DM yield of the crops and daily allowances of feed for animals the stocking density and urine patch coverage can be estimated. Due to the high yield of FB the stocking density on the FB was three times that of the KA treatment resulting in urine patch coverage of 61% of the FB area. Despite the average urine patch area on FB being nearly half the size of a KA urine patch, this is similar to the estimated 58% coverage under the KA system.

Conclusion

A simple urine meter device using an electronic data logger connected to a flow meter and attached to the vulva of dairy cows has provided new information on urine volume and urination frequency of cows grazing kale or fodder beet diets in winter. Knowledge of urine volume enabled estimates of paddock scale urine patch coverage by extrapolating information on wetted area under urine patches of respective treatments, though separate calibrations were required due to soil microtopography. This information can be used in conjunction with lysimeter data to calculate N losses. Future research is required to validate these results and determine temporal variation in cow behaviour and urine characteristics of urination events on N leaching risks.

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