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Automated monitoring of urination events from grazing cattle

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ABSTRACT

Urine patches deposited by grazing cattle represent 'hot-spots' of very high nitrogen (N) loading from which environmentally important losses of N may occur (ammonia and nitrous oxide emissions, nitrate leaching). Information on the quantities of N deposited to grazed pastures as urine, the spatial and temporal distribution of urine patches and how these may be influenced by pasture management practices is limited. The objectives of this study were to assess the potential of recently developed urine sensors for providing data on urination behaviour by grazing cattle and relate this to measurements of ammonia emissions from the grazed paddocks. A total of six trials were conducted across two sites; two on a 1 ha paddock at Easter Bush near Edinburgh using beef cattle (c. 630 kg live weight) and four on a 0.5 ha paddock at North Wyke in Devon using in-calf dairy heifers (c. 450 kg live weight). Laboratory calibrations were conducted to provide sensor-specific functions for urine volume and N concentration. The quantity and quality of data from the urine sensors improved with successive trials through modifications to the method of attachment to the cow. The number of urination events per animal per day was greater for the dairy heifers, with a mean value of 11.6 (se 0.70) compared with 7.6 (se 0.76) for the beef cattle. Volume per urination event (mean 1.8, range 0.4–6.4 L) and urine N concentration (range 0.6–31.5 g L^{-1}, excluding outliers) were similar for the two groups of cattle. Ammonia emission measurements were unsuccessful in most of the trials. The urine sensors have potential to provide useful information on urine N deposition by grazing cattle but suggested improvements including making the sensors lighter, designing a better method of attachment to the cow and including a more reliable location sensor.

1. Introduction

Cattle urine contains significant quantities of nitrogen (N), with concentrations typically in the range 2–20 g L^{-1} (Whitehead, 1995), mostly in a very labile form (Bristow et al., 1992). The relatively small area covered by a urine patch from cattle grazing at pasture therefore results in very high N loading rates to the soil, exceeding the capacity of the grass to fully utilise it. Urine patches therefore represent 'hot-spots' from which losses of N may occur through ammonia volatilisation, nitrate leaching and nitrous oxide emissions (Allen et al., 1996; Di and Cameron, 2007; Jarvis et al., 1989; Laubach et al., 2013) with potentially damaging impacts on the environment (Galloway et al., 2003).

The N content and spatial and temporal distribution of urine patches are important factors affecting these potential losses and may be influenced by cattle diet, grazing management, environment and season. Our ability to model N losses and utilisation in grazed pasture systems and to optimise management practices requires good information on cattle urination behaviour. In particular, model representation of the urine patch, with a high N loading to a small spatial area is important rather than assuming an even distribution of grazing N returns across the whole grazed paddock (e.g. Hutchings et al., 2007). Non-linearity between N loss and N loading to a urine patch (Ledgard, 2001) mean that scaling up based on estimates of average values for urine patch N loading may differ substantially from that which takes into account the variation in N concentration and volume per urination event and the possibility of urine patch overlap (Li et al., 2012). Additionally, it may be important to represent the spatial distribution of N returns in urine in relation to variation in soil and environment parameters (e.g. wetness, compaction, slope). However, to date, there have been few published data on urination behaviour by grazing cattle as field observations are difficult to make. Those that

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have been made suggest that urine patch distribution and overall spatial extent can be influenced by factors including fence line positions, water tank positions, field slopes and preferred night resting areas (Auerswald et al., 2010; Augustine et al., 2013; White et al., 2001).

Betteridge et al. (2010) described an automated urination sensor which, when used in conjunction with a GPS unit, could give information on the timing and location of urination events by grazing cattle or sheep. They showed that urine patch distribution was very non-uniform for sheep and cattle grazing on hill pastures in New Zealand. Further development of the sensor by Betteridge et al. (2013) enabled measurement of urine volume and N content for each urination event and reported that frequency distribution patterns of urinary N concentration could have a large effect on modelled N leaching loss. The sensors also had the potential to record location of urination events, using ZigBee communication (www.zigbee.org) by triangulation with fixed location ZigBee reference nodes around the grazed paddock.

The objective of our study was to assess the potential of the urine sensors to provide detailed spatial and temporal data on urination behaviour and urine N content for grazing cattle. A secondary objective was to determine the proportion of the urinary N excreted by the grazing cattle that was subsequently lost to the atmosphere via ammonia volatilisation.

2. Materials and methods

2.1. Urine sensors

Purposely designed urine sensors (AgResearch, Palmerston North, New Zealand) were used in the trials. The urine sensor was attached to the cow by gluing over the vulva, such that all urine flowed through the sensor, and was supported by attachment to the cows back. Development of the method of attachment and support continued throughout the trials from an initial configuration whereby Velcro straps were glued to the cow's back (Fig. 1a) to a final version where the weight of the sensor was better supported by a harness worn by the cow. Lateral movement of the sensor was minimised by supporting straps fixed to the lower end and a shroud was fitted to minimise risk of contamination by faecal material (Fig. 1b).

Urine flow through the sensor initiated sensor functioning and provided a time-stamp for the urination event. The urine flowed through a funnel within the sensor from which the majority drained away to the ground while a small subsample (10–20 mL) was retained in the bottom of the chamber. Urine volume for a given urination event was determined by recording the pressure head of urine (recorded every two seconds while urine was flowing) in the sensor funnel for the duration it takes to drain away. The area under the pressure × time curve was related to urine volume. Urinary N concentration was determined from the refractive index reading in the residual 10–20 mL of urine in the sensor. This residual urine was totally displaced by fresh urine at the next urination event; retention of this small volume of urine in the chamber minimised the likelihood of a mineral film forming on the refractive index sensor window. Urine sensors also included a ZigBee system for location of the sensor for each urination event relative to fixed position nodes located around the grazed paddocks.

The Rothamsted Research and SRUC Ethical Review Committees and associated professional veterinarian were involved throughout this study and were satisfied that the procedures and materials used did not adversely affect the cattle, with no significant skin damage around the vulva area from gluing and removal of the sensors and no impact on cattle behaviour. There were some problems in the earlier trials with the animals being aware of the sensor because of lateral movement e.g. while walking and this led to some instances of animal bucking and sensor detachment. However, as the method of attachment was improved, particularly through the use of lateral supports to minimise any lateral movement of the sensor (Fig. 1b), this was no longer a problem and from visual observations animals very quickly resumed normal behaviour after sensor attachment.

Fig. 1. Attachment of urine sensor to the cow: A, showing initial configuration using Velcro straps glued to cow; B, final configuration using a harness with top and side straps to support sensor weight and minimise lateral movement. GPS collar also shown on the beef cow in A.

Calibration functions were derived for each urine sensor for volume and N concentration using cattle urine collected from dairy cows during milking at a local dairy farm. Volume calibrations were performed by pouring volumes of between 1 and 4 L, in 0.5 L graduations, through the sensor and relating urine volume to the integral of the pressure × time curve. Nitrogen concentration calibrations were performed using cattle urine of known N concentration at four different dilutions and relating N concentration to the refractive index reading.

2.2. Trial sites

Two grazing trials were conducted in September and October 2012 using 14 beef cows (Charolais cross, Limousin cross and Aberdeen Angus cross, average live weight 630 kg) on a 1 ha paddock at Easter Bush, near Edinburgh, Scotland, and a further four trials conducted from July to September 2013 using between 7 and 12 in-calf dairy heifers (Holstein-Friesian, average live weight 450 kg) on a 0.5 ha paddock at North Wyke in Devon, England (Table 1). Both sites were permanent pasture, with total fertiliser N