Using a urine sensor to estimate nitrogen excretion by lactating dairy cows in Australian grazing systems

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Abstract

Ruminants excrete most of their N intake, with most of the N excreted in urine. As a result, urine is the greatest contributor of N losses to the environment in dairy systems worldwide, due to the high use of N. While quantifying N excretion will assist in the development of improved N management practices, measurement of urinary N is difficult in grazing dairy systems. A urine sensor developed by AgResearch, New Zealand which allows the determination of N concentration (%) and volume of each individual excretion event performed by grazing cows was tested in Australian conditions. Twenty Friesian-cross lactating dairy cows were fitted with urine sensors and data were recorded over a 48 hour period in spring 2014 and late winter 2015. A total of 420 urination events were recorded in this study. Urine volume excreted by these grazing lactating cows ranged from 8.2 to 43 L/day while urinary N concentration varied between 1.2 and 15.7 g N/L, similar to previously reported results. The average urination frequency was 18 times per day and average volume per event was 8.2 L/event. These data also showed that N concentration varies between time of the day and showed higher concentration in the early morning and afternoon.

Key Words

Urine volume, urinary nitrogen concentration, urine sensor, urine frequency

Introduction

Leaching of nitrate (NO_3^-) from agricultural soils has been a major cause of degradation of ground water (Castillo *et al.* 2000). Urine is major contributor of N leaching losses to the environment in grazing systems where ruminants excrete 75-95% of the N they ingest, most of which is excreted in urine (Selbie *et al.* 2015). In Australian dairy systems N use has steadily increased over the past 20 years as the industry has intensified (Stott and Gourley 2016). Nitrogen surpluses have been observed on many of these grazing system farms and high N excretion rates associated with large N intakes have been calculated (Gourley *et al.* 2012; Aarons *et al.* 2016). For most farms studied the N intakes were in excess of the recommended 400 g/cow/day above which most of the dietary N would be excreted in urine (Castillo *et al.* 2000). Many N cycling models and relationships have been developed to identify N excretion, particularly urinary N output from housed dairy cows (Jonker *et al.* 2002; Nennich *et al.* 2005). However, there is lack of information about urinary N excretion by dairy cows in grazing systems. Despite the high N excretion by dairy cows in Australian farms there is little data describing the urinary N output in these systems. The objective of this research was to quantify the variation in N excretion by grazing lactating dairy cows in Australia using a urine sensor, and to evaluate the feasibility of use of the sensor.

Methods

Study location

The study took place at the DEDJTR dairy research centre at Ellinbank, located in south eastern Australia during late spring 2014 and mid-winter 2015. Ten Friesian lactating cows were fitted with urine sensors for a period of 48 hours in September/October 2014 (spring) and another ten cows were fitted with the sensors in June/July 2015 (late winter). Between two and four cows were fitted with the sensors at each monitoring period and kept in small herds with other non-monitored cows. The animals were outdoors, rotationally grazing pasture and received additional concentrate at each milking. The monitored animals were returned to the dairy shed with their herds for milking twice daily, which usually occurred for all herds on the research farm between 6 and 8 am in the morning and between 3 and 4 pm in the afternoon. This research was carried out according to the DEDJTR Animal Ethics Committee proposal 2012-25.

Sample analyses
Urine samples collected from dairy cows at the research farm were immediately frozen until analysis. Sub-samples were analyzed for N concentration using the TruMac® N nitrogen analyzer developed by LECO Corporation; Saint Joseph, Michigan USA.

Urine sensor
AgResearch, New Zealand developed a urine sensor to measure urine volume and urinary N concentration of each event performed by a grazing cow (Betteridge *et al.* 2013). The basis of the sensor is a urine collector which is glued over the vulva of cow through which all urine passes to the sensor suspended below it. Urine volume is measured with a pressure sensor, while N concentration is measured with a refractive index sensor. The urine sensor has been deployed in research in New Zealand, and was selected for use in Australian grazing systems. Before application in the field with cows, the sensor was calibrated for both volume and N % concentration. Distilled water was used for the volume calibration, while urine collected from dairy cows was used for the N concentration calibration (Figure 1).

Figure caption appears below (annotations on chart): $y = 133.61x - 178.44$, $R^2 = 0.86212$. Y-axis: N concentration (%); X-axis: Refractive Index Values.
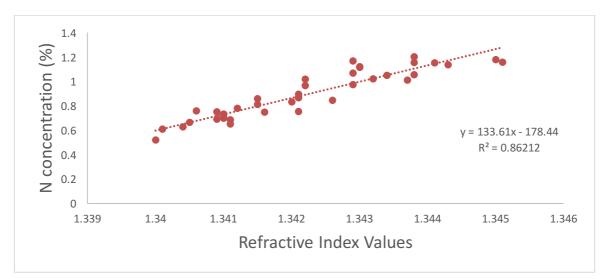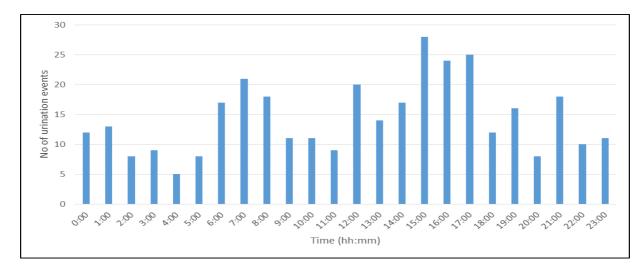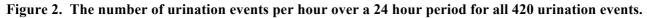
Figure 1. Calibration curve of N concentration measured in the laboratory versus refractive index values from the urine sensors for urine samples collected from grazing dairy cows.

Results
A total of 420 urination events were recorded over the two monitoring periods and both datasets are presented together. As expected the volumes excreted and the frequency of urination varied. Urine volume ranged from 8 to 43 L/day. Most of the morning urination events occurred early between 6 am and 8 am and similarly more urination events were observed in the afternoon between 3 and 5 pm (Figure 2). The greater number of urination events in the morning appeared to occur as cows were moved from their overnight paddock to the dairyshed for the morning milking. The greater number of events also observed in the afternoon occurred after the cows would have spent time in paddocks grazing and drinking following the morning milking. The average number of urination events was found to be between 4 and 18 times per day, and these results were close to the study of Aland et al. (2002) who found that grazing dairy cows urinated 9 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 at al. (2010) reported urination frequency of 0.5 events/hour/cow in lactating cows.

The urine volume per event was also variable, with an average urine volume per event of 2.0 L (range 0.24 to 8.23, Figure 3) and this result is consistent with Betteridge et al .(2013) who found the average urine volume per event to be 2.1 L for crossed bred dairy cows in grazing systems. Similar results were also found by Ravera et al. (2015) who found that average urine volume ranged from 8.7 to 47 litres/ day during their study of the effect of different winter fodder on volume of urine excreted by dairy cows.
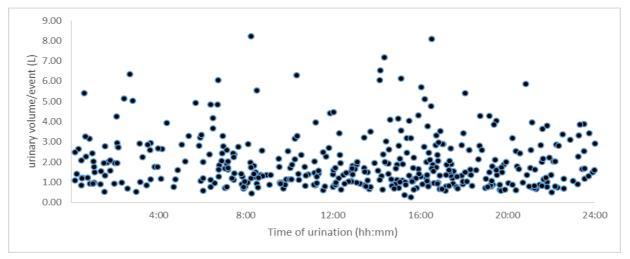
Figure 2. The number of urination events per hour over a 24 hour period for all 420 urination events.

Figure 3. The range in urinary volume per event over 24 hours for all urinations by 20 lactating dairy cows grazing pasture.
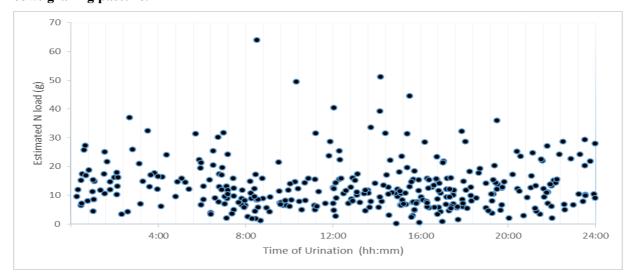

Figure 4. The range in N load of urination events over 24 hours by 20 lactating dairy cows grazing pasture.

The range in urinary N concentration varied between 1.2 and 15.7 g N/L. The load of N in each urination event varied and ranged from 0.9 to 64.3 g N/event (Figure 4). The data also showed a clear variation in

urinary N load during the day. Figure 4 reveals that high loads are recorded in the early morning from 6am to 8pm and in the afternoon period between 3am and 5pm. In addition to urine output, we assessed the feasibility of using this sensor. As reported by others (Misselbrook *et al.* 2016) we observed some difficulty with detachment of the sensors, requiring re-fitting on many days. In addition, the sensors were sometimes blocked by faecal material and therefore could not record urination activity. Despite these difficulties, the urine sensor enabled collection of urination data for lactating dairy cows while grazing Australian pasture systems.

Conclusion

Urine volume, urination frequency and urinary N concentration per event has been reported for lactating cows grazing Australian dairy systems for the first time in this paper. These data were measured using non-invasive attachment of calibrated urine sensors and were similar to that reported in the literature. The sensor technology enabled estimation of N excretion by cows grazing in paddocks and travelling to and from the dairy shed, despite the challenges associated with detachment and blockage. Further quantification of spatial variability in urine deposition will require combination of the urine sensor with GPS technology to better understand where the greatest N loads are deposited and therefore the potential for N leaching on farms.

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