Journal of Environmental Management 215 (2018) 166–176

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Spatially and temporally variable urinary N loads deposited by lactating cows on a grazing system dairy farm

Awais Ahmed [a], Rajneet Sohi [a], Rakhshan Roohi [a], Markandeya Jois [a], Peter Raedts [b], Sharon R. Aarons [c,*]

[a] School of Life Sciences, La Trobe University, Bundoora, Victoria 3083, Australia
[b] Dairy Centre, Tasmanian Institute of Agriculture, Cradle Coast Campus, 16-20 Mooreville Road, Box 3523, Burnie, Tasmania 7320, Australia
[c] Agriculture Victoria Research, Department of Economic Development, Jobs, Transport and Resources, 1301 Hazeldean Road, Ellinbank, Victoria 3821, Australia

ARTICLE INFO

Article history:
Received 25 September 2017
Received in revised form
5 March 2018
Accepted 11 March 2018

Keywords:
Urine patches
Excretion
Animal movement
Seasonal
GPS
Urine sensor

ABSTRACT

Feed nitrogen (N) intakes in Australian grazing systems average 545 g cow^{-1} day^{-1}, indicating that urinary N is likely to be the dominant form excreted. Grazing animals spend disproportionate amounts of time in places on dairy farms where N accumulation is likely to occur. We attached to grazing cows sensors that measure urine volume and N concentration, as well as global positioning systems sensors used to monitor the times the cows spent in different places on a farm and the location of urination events. The cows were monitored for up to 72 h in each of two seasons.

More urination events and greater urine volumes per event were recorded in spring 2014 (3.1 L) compared with winter 2015 (1.4 L), most likely influenced by environmental conditions and the greater spring rainfall observed. Mean (range) N concentration (0.71%; 0.02 to 1.52%) and N load (12.8 g cow^{-1} event^{-1}; 0.3 to 64.5 g cow^{-1} event^{-1}) did not differ over the two monitoring periods. However, mean (range) daily N load was greater in spring (277 g cow^{-1} day^{-1}; 200 to 346 g cow^{-1} day^{-1}) than in winter (90 g cow^{-1} day^{-1}; 44 to 116 g cow^{-1} day^{-1}) due to the influence of urine volume. Relatively greater time was spent in paddocks overnight (13.3 h) than in paddocks between morning and evening milking (6.4 h), compared with the mean numbers of urinations in these places (6.4 and 3.8 respectively). The mean N load deposited overnight in paddocks (89.6 g cow^{-1}) was more than twice that deposited in paddocks during the day (43.8 g cow^{-1}), due to the greater N load per event overnight, and was more closely linked to the relative difference in time spent in paddocks than in the number of urination events. These data suggest that routinely holding cows in the same paddocks overnight will lead to high urinary N depositions, increasing the potential for N losses from these places. Further research using this technology is required to acquire farm and environment specific urinary data to improve N management.

1. Introduction

Urine is the major route of N loss in dairy production systems (Bussink and Oenema, 1998; Di and Cameron, 2002; Oenema et al., 1997), and the potential for N loss has grown as N inputs in feed and fertiliser continue to increase. For instance, in Australia greater feed and fertiliser N use has occurred both in response to and despite the dependence on grazed pasture. Stott and Gourley (2016) reported that fertiliser N imports on to dairy farms had grown from about 20 kg N ha^{-1} in 1990 to approximately 90 kg N ha^{-1} in 2012, while purchased supplementary feed use grew by almost three-fold over the same period. This intensification occurred as the number of dairy farms halved, with the greater input of N to a smaller land area resulting in N surpluses of 158 kg N ha^{-1} in 2012, up from 54 kg N ha^{-1} two decades previously (Stott and Gourley, 2016).

Nitrogen surpluses on Australian dairy farms are similar to those reported for other grazing systems. For example, mean annual farm N surpluses of 150 and 161 kgN ha^{-1} were reported for grazing system dairy farms in New Zealand (Scarsbrook and Melland, 2015). Likewise, large mean annual farm gate balances have also been observed for grass-based Irish dairy farms (243 kg N ha^{-1}; ranging from 87 to 389 kg N ha^{-1}), although these were

* Corresponding author.
E-mail address: Sharon.Aarons@ecodev.vic.gov.au (S.R. Aarons).

https://doi.org/10.1016/j.jenvman.2018.03.046
0301-4797/

substantially higher than those in Australia and New Zealand (Treacy et al., 2008), before declining to a mean of 175 kg N ha^{-1} after the introduction of good agricultural practice (GAP) regulations (Mihailescu et al., 2014). On these grazing system farms fertiliser and concentrate N inputs were linked to N surpluses.

Surplus N is considered an indicator of potential N leaching, ammonia volatilisation and denitrification losses (Børsting et al., 2003). For example, using long term streamflow and water quality data, Smith and Western (2013) showed that stream N concentrations were linked to increased milk production, of particular importance since total milk yields doubled in the first decade of their study. Beukes et al. (2012) also considered N surplus a good indicator of N leaching losses as their experimental and modelled data showed increasing losses as N surpluses grew.

Nitrogen losses in dairy systems are primarily associated with urine and dung due to the low efficiency of use of dietary N by ruminants (Dijkstra et al., 2013). However, nitrous oxide (N_2O) and ammonia (NH_3) emissions are greater from urine (Laubach et al., 2013; Oenema et al., 1997) than dung, and nitrate (NO_3) leaching losses increase considerably due to inputs of urine N in grazed pastures (Di and Cameron, 2002). For instance, N_2O emissions ranged from 0.1 to 9.9% of excreted N (Oenema et al., 1997) with generally greater amounts emitted from urine (mean 1.5%) than dung (0.4%). While excreta deposition and management contribute to the majority of NH_3 losses on dairy farms (Bussink and Oenema, 1998), Laubach et al. (2013) observed that urine was the dominant contributor (86%) to NH_3 volatilisation in the eight days after excreta were deposited on pasture; greater than the proportion urine comprises of total N deposited by cattle. Furthermore, NH_3 loss from urine N was more than twice that from dung. Similarly, nitrate (NO_3) leaching losses from grassland increase considerably when pastures are grazed due to inputs of urine N which resulted in leaching of 120 mg NO_3-N L^{-1} (Di and Cameron, 2002).

The importance of excreta in N pollution by dairy production systems is due to positive linear relationships observed between intake and output, where urine N was between 38 and 68% of N intake, while faecal N comprised only between 20 and 39% (Dijkstra et al., 2013). However, an exponential relationship between urinary and dietary N above a daily intake of 400 g N cow^{-1} has also been described (Kebreab et al., 2001). With dietary N for Australian grazing systems estimated to range from 268 to 983 kg N cow^{-1} day^{-1} (mean of 545 kg N cow^{-1} day^{-1} (Aarons et al., 2017b), urine N excretion and deposition is likely to be considerable in these systems.

Deposition of excreta has been shown to be closely linked to the time animals spend in particular locations around farms and within paddocks (Draganova et al., 2016; White et al., 2001), with cow placement influenced by both environmental and management practices (Aarons et al., 2017a). For example, cows voided near water troughs more often during warmer weather (White et al., 2001). Cows also spent longer and excreted more in paddocks where they were placed over night (Wardrop, 1953). Overnight paddocks are also typically located closer to the dairy shed (Aarons et al., 2017a), explaining previously observed nutrient accumulation near the dairy sheds (Fu et al., 2010; Gourley et al., 2015; McCormick et al., 2009). Thus methods to quantify both urinary N output and the locations where excreta are deposited will assist in improving nutrient management on grazing system farms.

Observational methods have historically been used to monitor urination events by grazing animals (e.g. Wardrop, 1953; White et al., 2001), but more recently various technologies have been developed to assist with assessing the temporal and spatial deposition by these animals of both urinations as well as urinary volumes and N concentration. For example, flow meters were used to quantify urination frequencies and volumes (Draganova et al., 2016), and to determine the impact of diet on urine volumes (Edwards et al., 2015; Ravera et al., 2015) for dairy cattle grazing pasture. A sensor that can record urine events, volumes and N concentrations was evaluated on dairy and beef cattle in New Zealand and the UK (Betteridge et al., 2013; Misselbrook et al., 2016), and recommended as a suitable tool for quantifying urinary N, enabling estimation of N leaching or volatilisation in grazing systems. Thus, when these sensors were used in conjunction with global positioning systems (GPS) technologies, the within paddock variation in urine deposition could be monitored to identify potential critical source areas for N losses (Betteridge et al., 2013; Draganova et al., 2016; Misselbrook et al., 2016).

Previous research showing spatial and temporal variation in the time lactating dairy cows spend in different places on grazing system farms was used to estimate N deposition to these locations (Aarons et al., 2017a, 2017b). However little research has been undertaken to quantify the temporal variation in excreta, particularly urinary, deposition in these systems. In the US, White et al. (2001) reported that 84% of urinations occurred in paddocks where the cows spent 86% of their time. Wardrop (1953) suggested that transfer of nutrients from the day paddocks could occur as twice as many urinations were deposited in night paddocks where the cows spent 60% of their time on a UK farm. As observational methods were used in both cases, urinary N loads deposited could not be estimated.

We deployed a urine sensor to record urination events, urinary volumes and N concentration of lactating cows as they grazed pasture paddocks and while moving around a dairy farm. Global positioning systems sensors were also used to record the time the monitored animals spent in the various places the cows visited and the sites of urination events in those locations. Thus the aim of this research was to measure urinary N loads deposited by dairy cows to different places on a farm and over different seasons. We use our results to recommend animal and N management improvements on grazing system farms.

2. Materials and methods

The study took place at the National Dairy Centre, Ellinbank, in the Gippsland region of south eastern Australia (−38.243558; 145.936153). The dairy farm at the Centre is used for a variety of research projects of relevance to regional and national farmers. The herds consist of Friesian and Friesian-cross herds that are managed as different sized groups for experimental and other purposes as required. The animals rotationally graze rainfed pasture paddocks consisting primarily of ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.). The Gippsland climate is temperate (Table 1) with the lowest temperatures in June, July and August (min − 5.4, 4.7, 4.9 °C; max − 13.6, 13.1, 14.2 °C, respectively; Bureau of meteorology station number 85283) and the highest average rainfall in September and October (75.0, 75.2 mm respectively) for the last 30 years (http://www.bom.gov.au/climate/data/).

2.1. Metabolism stall evaluation

The urine sensors were evaluated on lactating dairy cows in metabolism stalls in the animal house at the Centre, to assess the ability of the sensors to capture all urination events. Six sensors were attached on two occasions to groups consisting of two and four cows, respectively. The cows were also fitted with separators to enable collection of all urination events after passing through the sensor. All urination events between 8:00 a.m. and 8:00 p.m. were recorded manually and a sub-sample collected and stored immediately at −20 °C. These multiparous (second to sixth lactation) cows ranged in age from 5 to 9 years and were 367–446 days in