BRIEF COMMUNICATION: Urinary nitrogen excretion and water balance of dairy heifers fed cut plantain or perennial-ryegrass pastures

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Abstract

The objective of our study was to quantify the effect of feeding plantain (PL) or perennial ryegrass (RG) to dairy heifers on urinary nitrogen (N) excretion and water balance. In an indoor cut-and-carry system, four Jersey × Friesian dairy heifers were grouped and randomly assigned to one of two dietary treatments of RG or PL for two weeks. Daily drinking water intake was lower (P=0.010; 2.8 vs 6.9 L), and forage (P=0.038; 53.7 vs 29.1 L) and total (P=0.046; 56.5 vs 36.0 L) water intake were greater for PL than for RG, respectively. Heifers fed PL excreted more (P=0.009) water in faeces and urine than did heifers fed RG (48.9 vs 21.9 L/day, respectively). Urine N% was lower (P=0.008; 0.23 vs 0.62%) and daily urine volume was greater (P=0.003; 35.8 vs 15.1 L/heifer) for PL than those of RG, respectively. Total urinary N excretion was similar between PL (91.1 g/day) and RG (96.7 g/day). These results indicate that, in comparison with RG, feeding PL to dairy heifers does not reduce urinary N output, but reduces urinary N concentration, due to a greater urine volume.

Keywords: dairy heifers; plantain; urinary nitrogen; water balance; ryegrass

Introduction

Reducing the environmental footprint from the dairy farming sector has increasingly become a research focus in New Zealand since the implementation of nitrate-leaching regulations (Ministry of the Environment, 2011). The nitrogen (N) deposited in urine patches from cows grazing perennial ryegrass and white clover pasture is a major contributor to on-farm N pollution, primarily due to these swards delivering N in excess of animal requirements (Pacheco & Waghorn 2008). Recent data indicated lower urinary N concentration from dairy cows grazing a mixed sward containing ryegrass, white clover, plantain and chicory compared to those grazing a conventional ryegrass-white clover sward (Woodward et al. 2012; Totty et al. 2013; Bryant et al. 2017). However, urinary N concentration in those studies was measured from spot samples collected twice daily (one each after morning and afternoon milking), and therefor; may not reflect total urinary N load from dairy cattle fed divers pasture.

Further, in comparison to ryegrass-white clover, plantain has been identified to have a diuretic effect, leading to increased urine volume and thus reduced urine N concentration of dairy heifers (Cheng et al. 2017) and dairy cows (Box et al. 2017). However, daily urine volume was not measured directly in these studies and, therefore, estimates used may not accurately reflect true urine volume and subsequent urinary N excretion. Consequently, whether the reduction in urine N concertation from dairy cattle fed plantain is a result of greater urine volume, alteration in N partitioning, or a combination of both, is still unclear. Further studies measuring urine volume and water balance for dairy cattle are required to quantify the effect of plantain on urinary N excretion and water balance. Therefore, the objective of this study was to quantify the effect of feeding cut plantain forage to dairy heifers on urinary N excretion and water balance in comparison to perennial ryegrass.

Materials and methods

Treatments and measurements in this study were approved by the Lincoln University Animal Ethics Committee # AEC 2018-42.

Experimental site, design and management

This study was conducted at the Lincoln University's Johnson Memorial Lab, Lincoln, New Zealand, from 26 Oct to 8 Nov 2018. Four Jersey × Friesian heifers were grouped into two groups of two heifers based on body weight (303±2.9 kg), age (448±4.2 days) and breeding worth (144±18.9 NZ$), and randomly assigned to one of two dietary treatments of cut perennial ryegrass (*Lolium perenne* L.) pasture (RG) or plantain (*Plantago lanceolate* L.*cv* Agritonic; PL). The study was conducted over a period of two weeks, including 11 days of acclimation to diet and three days of measurement. Heifers from each treatment were housed in pens (two heifers per pen) with sawdust bedding during the first week of study, and in individual metabolism crates during the second week of study. Fresh-cut herbage was offered to heifers at 1000 and 1600 h. Herbage allocation was set to allow 400-500 g DM feed refusals in feeding bins, and each heifer was allowed *ad libitum* access to water.

Measurements and analysis

Drinking water intake (readings of measurable troughs) and herbage intake (offered minus refusals) were recorded at 1000 and 1600 h daily during the measurement period. Herbage samples were collected twice daily immediately before feeding for each heifer to determine DM content. Herbage samples were collected from the field immediately after forage was cut, once during the measurement period, to determine chemical composition. Feed samples were freeze dried, ground through a 1.0-mm sieve and analysed for N content, neutral detergent fibre (NDF), acid detergent fibre (ADF), water-soluble carbohydrate, dry organic

matter digestibility (DOMD) by calibrated near infra-red spectroscopy. Metabolisable energy (ME) of feed was estimated based on the equation ME (MJ/kg) = DOMD% × 0.16 (AFRC 1993).

On day 11, a sterile Foley catheter (14 Fr, 55 cm, 30 cc; ClearView, Smiths Medical, USA) was placed into the urethra for total collection of urine. Urine drained into sealed container containing sulphuric acid (1 ml of 50% sulphuric acid per 50 ml of urine). Daily urine volume was recorded (L/day) and a representative sample (5% of total volume) was collected, stored at -20 ºC, and later analysed for N content using Variomax CN Analyser (Elementar Analysensystem, Germany). Faeces were collected into a tray sitting underneath the back end of each metabolism crate at 0930 and 1630 h daily during the measurement period. Faeces weight was recorded and a representative sample (10% of total volume) was collected, stored at -20 ºC, and later oven-dried to determine DM content.

Statistical Analysis

GenStat 18th Edition was used for analysis. All measurements were analysed using one-way ANOVA with herbage type as treatment and heifer as replicate. Results were declared significant at $P < 0.05$.

Results

Chemical composition and ME of ryegrass and plantain are presented in Table 1. DM content of forage was 22% lower for plantain than ryegrass. The content of N and ME, and DOMD of forage were also numerically lower for plantain than ryegrass.

The effects of RG and PL on DM intake, water intake and excretion, and urinary N excretion of dairy heifers are presented in Table 2. Herbage DM intake was similar between treatments (6.9 vs 8.3 kg DM/day for RG and PL, respectively). Daily drinking water intake was lower (P=0.010; 2.8 vs 6.9 L), and forage (P=0.038; 53.7 vs 29.1 L) and total (P=0.046; 56.5 vs 36.0 L) water intake were greater for PL than for RG, respectively. Heifers fed PL excreted more (P=0.009) water in faeces and urine than did heifers fed RG ((48.9 vs 21.9 L/day, respectively). Urinary N concentrating was lower (P=0.008; 0.23 vs 0.62%) and daily urine volume was greater (P=0.003; 35.8 vs 15.1 L) for PL than RG, respectively. Total urinary N excretion (g/day) was similar between PL (91.1) and RG (96.7).

Table 1 Dry matter (%), chemical composition (g/kg DM) and metabolisable energy content (MJ/kg DM) of ryegrass and plantain fed to heifers for 14 days

	Ryegrass	Plantain
Dry matter	190	148
Nitrogen	34	28
Water-soluble carbohydrate	79	123
Neutral detergent fibre	500	371
Acid detergent fibre	261	234
Dry organic matter digestibility	725	669
Metabolisable energy	11.6	10.7

Table 2 Effect of feeding cut ryegrass (RG) and plantain (PL) to dairy heifers for 14 days on average herbage DM intake, water balance, urine volume and urinary N excretion

	Treatment		SEM	P value
	RG	PL		
Herbage intake (kg DM/day)	6.9	8.3	0.53	0.198
N intake (g/day)	233	232	15.30	0.958
Water				
Drinking water intake (L/day)	6.9	2.8	0.30	0.010
Forage water intake (L/day)	29.1	53.7	3.51	0.038
Total water intake (L/day)	36.0	56.5	3.21	0.046
Total water excretion (L/day)[1]	21.9	48.9	1.81	0.009
Water balance[2]	14.1	7.5	1.44	0.085
Urine				
Urine N%	0.62	0.26	0.022	0.008
Urine volume (L/day)	15.1	35.8	0.76	0.003
Urinary N excretion (g/day)	96.7	91.1	6.44	0.602

[1]Total water excreted in urine and faeces; [2]Water balance = total water intake – total water excretion

Discussion

The objective of this study was to quantify the effect of feeding PL to heifers on daily urine volume, urinary N excretion and water balance, using a total collection method for urine (i.e. urine catheters). Despite similar N intake, urinary N concentration was 2.4 times lower for heifers fed PL than for those fed RG. This is in agreement with previous studies that reported lower urinary N concentration for cows (Totty et al. 2013; Box et al. 2017) and heifers (Cheng et al. 2017) fed plantain than their counterparts fed conventional ryegrass-white clover pasture. The present study supports the hypothesis that this effect is mainly a result of greater urine volume for PL than RG, which diluted urinary N concentration.

The greater urine volume for heifers fed PL compared with RG is due to two major factors. First, the greater total water intake for PL than RG, which resulted in greater water excretion. The greater water content of PL resulted in greater forage water intake for heifers fed PL than that of those fed RG. This may have resulted in the lower water intake from the trough for heifers fed PL compared with RG. However, because proportion of daily water intake from troughs was relatively small for heifers in both treatments (19% and 5% for RG and PL, respectively), greater forage water intake resulted in 2.3 times greater total water intake for heifers fed PL than those fed RG. Similar results were reported in the study of Cheng et al. (2017) and Box et al. (2017). The second factor is the diuretic effect of plantain (O'Connell et al. 2016). Plantain has a greater content of secondary compounds (e.g. aucubin and catapol; Tamura & Nishibe 2002), and minerals (i.e. sodium and potassium; Cheng et al., 2017; Cheng et al., 2018) than RG, which are associated with diuretic effects (Ledgard et al. 2015; O'Connell et al. 2016). This is supported by reduced water retention (i.e. smaller difference between total water intake

and water excreted in urine and faeces) in heifers fed PL compared with RG. The similar urinary N excretion (g/day) among treatments suggest that the reduction in urinary N concentration was a result of larger urine volume for heifers fed PL compared to those fed RG. These findings suggest that in comparison with RG, feeding PL to dairy heifers reduces urinary N concentration as a result of greater urine volume. Therefore, plantain may provide an alternative forage options to mitigate dairy farms' N loss to the environment.

We acknowledge that the data presented in this study were only collected from four animals (two heifers per treatment). However, the differences in urine volume and urinary N concentration between treatments were great enough to detect statistical differences and indicate this is a true result.

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References

AFRC 1993. Energy and protein requirements of ruminants: an advisory manual prepared by the AFRC Technical Committee on Responses to Nutrients. Commonwealth Agricultural Bureaux, Farnham Royal, U.K.

Box LA, Edwards GR, Bryant RH 2017. Milk production and urinary nitrogen excretion of dairy cows grazing plantain in early and late lactation. New Zealand Journal of Agricultural Research 60: 470-482.

Bryant R, Miller M, Greenwood S, Edwards G 2017. Milk yield and nitrogen excretion of dairy cows grazing binary and multispecies pastures. Grass and Forage Science 72: 806-817.

Cheng L, Judson HG, Bryant RH, Mowat H, Guinot L, Hague H, Taylor S, Edwards GR 2017. The effects of feeding cut plantain and perennial ryegrass-white clover pasture on dairy heifer feed and water intake, apparent nutrient digestibility and nitrogen excretion in urine. Animal Feed Science and Technology 229: 43-46.

Cheng L, Al-Marashdeh O, McCormick J, Guo X, Chen A, Logan C, Tao JZ, Carr H, Edwards G 2018. Live weight gain, animal behaviour and urinary nitrogen excretion of dairy heifers grazing ryegrass–white clover pasture, chicory or plantain. New Zealand Journal of Agricultural Research 61: 454-467.

Environment Mft 2011. National policy statment for freshwater managment. Ministry for the Environment, 11 pp.

Ledgard SF, Welten B, Betteridge K 2015. Salt as a mitigation option for decreasing nitrogen leaching losses from grazed pastures. Journal of the Science of Food and Agriculture 95: 3033-3040.

O'Connell C, Judson H, Barrell G 2016. Sustained diuretic effect of plantain when ingested by sheep. Proceedings of the New Zealand Society of Animal Production 76: 14-17.

Pacheco D, Waghorn GC 2008. Dietary nitrogen definitions, digestion, excretion and consequences of excess for grazing ruminants. Proceedings of the New Zealand Grassland Association 70: 107-116.

Tamura Y, Nishibe S 2002. Changes in the concentrations of bioactive compounds in plantain leaves. Journal of Agricultural and Food Chemistry 50: 2514-2518.

Totty V, Greenwood S, Bryant R, Edwards G 2013. Nitrogen partitioning and milk production of dairy cows grazing simple and diverse pastures. Journal of Dairy Science 96: 141-149.

Woodward S, Waghorn G, Bryant M, Benton A 2012. Can diverse pasture mixtures reduce nitrogen losses. Proceedings of the 5th Australasian Dairy Science Symposium. Pp. 463-464.