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Effects of a daily dose of zeolite on rumen ammonia of lactating dairy cows consuming fresh-cut ryegrass pasture

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Abstract

Zeolites are aluminosilicates that can be safely fed to ruminants on a daily basis. They have a strong affinity for cations, including ammonium (NH₄⁺), which creates the potential to adsorb excess ammonium released in the rumen and reduce urinary nitrogen (N) excreted. The main objective of this proof-of-concept study was to evaluate the effect of a single dose of 300 g of zeolite, deposited into the rumens of cannulated dairy cows before the main morning meal of fresh-cut ryegrass pasture, on changes in rumen ammonium concentrations over the following 8 h. The two-week trial was a cross-over design with 12 cows, either fed ryegrass as a sole diet (Control) or with zeolite (Zeolite). There was a consistent trend for rumen ammonium concentrations in the zeolite-treated cows to increase more slowly over time, and were lower than control cows 8 h after the zeolite was given (P = 0.08). This study provides some indications that a daily dose of zeolite, fed at the onset of the morning meal, may have a moderating effect on rumen ammonium concentration, and reduce plasma urea N concentrations in lactating dairy cows fed a ryegrass-dominant diet.

Keywords: cannulated cows; N metabolism; N mitigation; plasma urea N

Introduction

Nitrogen utilization for milk production by grazing dairy cows ranges from about 14-25% of dietary N intake. The lowest values are associated with pastures containing high concentrations of crude protein (CP), but are exacerbated by low milk production (Waghorn et al. 2007; Pacheco & Waghorn 2008). In pastoral dairying systems, approximately 80% of the urinary N is discharged onto pastures (McLeod et al. 2009), with the remainder on races, feeding pads and yards. Up to 55% of urinary N on pastures can leach, depending on the N load per urine patch (kg/ha) and the time of year (Romera et al. 2017). Under New Zealand conditions about 2% of urinary N can be lost as nitrous oxide, depending on conditions, such as soil moisture (de Klein & Ledgard 2005). These losses demonstrate the need to evaluate feeding-management strategies to reduce urinary N excretion.

Compounds, such as condensed tannins, added to the animal diet, have the potential to reduce N leaching losses by shifting the site of excreted N from urine into the faeces, thereby reducing the amount of N excreted in urine (Selbie et al. 2015). However, care should be taken to avoid reductions in intakes or digestibility.

Zeolites are aluminosilicates that have a porous structure with a very large surface area (120-130 m²/g) (www.optimate.co.nz), that enables absorption, release and exchange of chemicals, nutrients and toxins. Clinoptilolite and Mordenite are two types of zeolites occurring in natural abundance especially in volcanic areas, including parts of New Zealand. These have a high ion exchange capacity (100-120 meq/100g) and affinity for ammonium ions and other cations (K⁺, Mg⁺, Ca⁺, Na⁺; Weatherly & Miladinovic 2004). New Zealand zeolites are unique in that they are geologically young, free from amorphous material, have a particularly open, soft structure, and are relatively unaffected by pH and temperature, enabling a range of applications such as eliminating odour, cleaning up oil spills, and slow release of absorbed water and dissolved nutrients in sports turf (www.bmpnz.co.nz). A preliminary field study on a commercial dairy farm showed that a natural zeolite feed additive can reduce plasma urea N in dairy cows and subsequent modelling indicated that this may lead to a reduction in urinary N excretion (K. Stelwagen, unpublished data).

It has been hypothesised that zeolites fed to ruminants have the potential to adsorb excess ammonium, and can release it as rumen ammonium concentrations decline (Mumpton & Fishman 1977; Bosi et al. 2002). Zeolites are able to adsorb and also release K⁺, Mg⁺, Ca⁺, Na⁺. Jorgensen and Theilgaard (2014) demonstrated the value of feeding synthetic sodium aluminium silicate to non-lactating cows to prevent clinical and subclinical parturient hypocalcaemia.

The main objective of this proof-of-concept study was to evaluate the effect of a single dose of zeolite deposited in the rumen before the main morning meal, on changes in rumen ammonium concentrations over time (hours) in dairy cows consuming fresh-cut ryegrass herbage. A secondary objective was to determine the potential effect of zeolite on plasma urea N, milk urea N, urinary N, and faecal N concentrations after feeding.

Materials and methods

Experimental design

The trial was approved by the Ruakura Animal Ethics committee (Approval 14025) and conducted at the DairyNZ Lye research farm in Hamilton, New Zealand, during November 2016. Twelve rumen-cannulated lactating
Sample processing

The DM% of pasture offered to the cows in the tie-stall barn on the measurement days was determined by oven drying triplicate subsamples (150±5 g fresh weight) to a constant weight (48 h) at 95°C. Chemical composition of oven-dried samples were determined using near infrared spectroscopy by Massey University Nutrition Laboratory.

Immediately following the collection of the rumen liquor samples, the pH (EcoScan pH meter; Eutech Instruments, Singapore) was measured and a 6-mL sample of liquor from each cow was retained and acidified with 0.2 mL of 50% hydrochloric acid (HCl), mixed and centrifuged (1120 × g, 10 min, 4°C). The supernatants were stored at −20°C for determination of NH₄⁺ concentration by colorimetry using phenol plus nitroprusside reagents (Weatherburn 1967).

Blood samples were placed on ice immediately following their collection and later centrifuged at 3000 × g for 10 min at 4°C. Plasma was aspirated and stored at −20°C for future analysis.

Milk urea N (PM and AM samples analysed separately) and plasma urea N concentrations were measured using the kinetic UV assay for urea/BUN package (Cobas®) in the Roche Modular Analyser (Gribbles Veterinary, Hamilton). Faecal and urine (after being acidified) samples were frozen (−20°C) until determination of total N using a combustion elemental analyser with thermal conductivity detection (Eurofins NZ Laboratory Services Limited, Auckland).

Statistical analysis

Intake, milk yield, and milk composition data were analysed using analysis of variance, with cross-over period and treatment included as fixed effects and cow as random effect. Results are presented as means and standard deviation and P-value for the effect of treatment. The rest of the data were analysed using mixed-models approach for repeated measures analysis of variance (Proc Mixed, SAS 9.3). Rumen NH₄⁺, as well as urinary, faecal, and plasma urea N were analysed both as absolute values and as difference from pre-dose baseline. Milk urea N was

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean ± SD</th>
<th>Control</th>
<th>Zeolite</th>
<th>P-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture DMI between 7 am and 3 pm (kg)</td>
<td>9.1 ± 2.15</td>
<td>9.5 ± 2.84</td>
<td>0.773</td>
<td></td>
</tr>
<tr>
<td>Milk yield (kg/day)</td>
<td>19.5 ± 3.22</td>
<td>19.9 ± 3.28</td>
<td>0.132</td>
<td></td>
</tr>
<tr>
<td>Milk fat (%)</td>
<td>4.3 ± 0.53</td>
<td>4.4 ± 0.57</td>
<td>0.890</td>
<td></td>
</tr>
<tr>
<td>Milk protein (%)</td>
<td>3.4 ± 0.25</td>
<td>3.4 ± 0.19</td>
<td>0.909</td>
<td></td>
</tr>
<tr>
<td>Milk lactose (%)</td>
<td>4.9 ± 0.16</td>
<td>4.9 ± 0.15</td>
<td>0.850</td>
<td></td>
</tr>
<tr>
<td>Milk urea N (mmol/L)</td>
<td>3.92 ± 1.804</td>
<td>3.97 ± 1.769</td>
<td>0.924</td>
<td></td>
</tr>
<tr>
<td>Plasma urea N pre-feeding (mg/100 mL)</td>
<td>12.72 ± 1.901</td>
<td>13.09 ± 1.458</td>
<td>0.971</td>
<td></td>
</tr>
<tr>
<td>Plasma urea N post-feeding (mg/100 mL)</td>
<td>15.70 ± 2.017</td>
<td>14.56 ± 1.903</td>
<td>0.061</td>
<td></td>
</tr>
<tr>
<td>Urine N (g/100 g)</td>
<td>0.63 ± 1.206</td>
<td>0.66 ± 0.114</td>
<td>0.399</td>
<td></td>
</tr>
<tr>
<td>Faecal N (g/100 g)</td>
<td>2.90 ± 0.186</td>
<td>2.76 ± 0.132</td>
<td>0.013</td>
<td></td>
</tr>
</tbody>
</table>

* Treatment did not affect concentrations before or after tie-stall feeding
analysed as absolute value. The models included time relative to start of treatment (7 am; 0 h on the measurement days), treatment, and their interaction, as well as cross-over period as fixed effects and cow as random effect. Pre-dose baseline results were included as covariate for the analyses of difference from pre-dose baseline. Results are presented as least-squares means and standard error of the difference (SED) or 95% confidence interval. Significance was declared if P<0.05.

Results
The pasture fed during measurement periods averaged 15.4±0.6% DM and the chemical composition (mean ± sd) was CP, 17.7±0.5; neutral detergent fibre (NDF) 44.3±2.0, ash 9.2±0.6 and lipid 3.3±0.3. Readily fermentable carbohydrate (100 - (percentage CP + NDF + ash + lipid)) averaged 25.6% of the DM whilst predicted metabolisable energy (MJ/kg DM) was 10.7±0.4 and organic matter digestibility was 78.6±4.3%. Dietary cation anion difference was 583.9±49.9 meq/kg DM.

The daily dose of zeolite did not affect intakes, milk yield or composition (Table 1). There was no overall effect of the zeolite treatment on rumen ammonium concentrations (P=0.29, Table 2). Rumen ammonium concentrations did increase after feed was offered (P=0.001), and although there was no treatment x time effect after feed was offered (P=0.49), the trend was for lower concentrations in Zeolite cows at 8 h (P=0.08, Table 2). The slower increase over time in rumen ammonium concentrations in the zeolite cows was evident from about 3 h after feeding, and the effect remained for the zeolite treated cows (Fig. 1).

Plasma urea N was similar for both treatments prefeeding and trended lower in Zeolite compared with Control cows in the measurements taken 8 h after the treatment (P=0.06). However, the zeolite treatment had no effect on milk urea N or urinary N concentrations (Table 1) and the lower N concentration in faecal DM of cows given zeolite (P<0.05) was probably a consequence of dilution by undigested zeolite.

Discussion
The increase in rumen ammonium concentrations in both control and zeolite cows approximately 2 h after the onset of feeding is in agreement with other studies in which hourly measurements were taken from rumen-cannulated dairy cows (Hristov et al. 2004; Olijhoek et al. 2016). There was a consistent trend for rumen ammonium concentrations to increase at a slower rate in zeolite-treated cows from 3 h after dosing, with the difference between concentrations approaching significance at the 8-h sampling (P=0.08), indicating that zeolite was affecting ammonium concentrations. This trend of lower ammonium concentrations in zeolite-treated animals, suggests that the mean 24 h rumen ammonium concentrations could be reduced by zeolite treatment. A longer sampling duration after zeolite treatment, for example two-hourly measurements over 24 h, is required to confirm this hypothesis.

Lower rumen ammonium concentration corresponds with lower plasma urea N concentrations, and this may affect a reduction in urinary N excretion (Kebreab et al. 2001), especially if ammonium is bound to the zeolite and excreted in faeces.

However, despite this significant difference in plasma urea N concentrations, there were no effects on concentration of milk urea N, or urinary N measurements. This was unexpected since Gustafsson and Palmquist (1993) and Rodriguez et al. (1997) reported close associations between concentrations of milk and blood urea, with a 1- to 2- h lag between blood and milk urea peaks. In this study, milk urea concentrations (approximately 4 mmol/L; 24 mg/dL) were at the low end of the ‘normal’ range for mid-lactation dairy cows in New Zealand (DairyNZ 2017), probably because of the low dietary CP content (17.7%) compared with requirements of about 18% for lactating dairy cows (Pacheco & Waghorn 2008).

This study provides an indication that a daily dose of zeolite, fed prior to the morning meal, may have a moderating effect on rumen ammonium concentration, with a consequent reduction in plasma urea N concentrations of lactating dairy cows fed a ryegrass-dominant diet. However,
the effects of zeolite on rumen ammonium concentrations were small, without clear effects on digestion and milk composition, despite relatively low dietary CP.

Acknowledgements

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