Dry matter intake and nitrogen losses of pregnant, non-lactating dairy cows fed kale with a range of supplements in winter

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Abstract

An outdoor winter-feeding study conducted over 14 days using 40 Friesian-Jersey cross dairy cows measured dry matter (DM) intake and nitrogen (N) excretion of cows fed kale with either barley straw (S), whole crop barley silage (WCBS) and *Lotus pedunculatus* silage (LS) fed with (LS+PEG) or without polyethylene glycol (LS-PEG). Treatment groups did not differ in DM utilisation of kale (80%) or apparent intake of kale (11.6 kg DM/cow/d). Total daily intake of N was lowest for S, intermediate for WCBS and highest for LS+PEG and LS-PEG (280, 323, 350 and 352 g N/cow/d, respectively). Urinary N excretion was lower ($P < 0.05$) on kale diets supplemented with either S or WCBS (202 and 186 g N/cow/d respectively) compared with LS+PEG and LS-PEG (227 and 239 g N/cow/d respectively). Supplement treatment did not affect total faecal N excretion but faecal N% was higher ($P < 0.05$) in LS treatment groups (3.05% in LS+PEG and 3.28% in LS-PEG), compared with WCBS (2.74%) and S (2.43%). This study indicates that the current commonly used feeding system of kale, supplemented with straw, is a feeding system that has a low urinary N excretion compared with alternatives.

Keywords: kale; condensed tannin; *Lotus*; barley; straw; silage; nitrogen excretion

Introduction

In South Island dairy systems, non-lactating, pregnant spring-calving cows are often wintered outdoors, away from the milking platform on brassica crops. Cool season brassicas such as kale (*Brassica oleracaea*) are commonly used because of high dry matter (DM) yields and ability to maintain high quality feed throughout winter (Judson & Edwards 2008). Cows are often break fed kale supplemented with barley straw or grass silage. The supplements are fed to maintain effective levels of fibre in the diet and modify intake rate and behaviour (Judson & Edwards 2008). However, the high stocking densities used in these feeding systems create potential environmental problems as nitrogen (N) excretion in urine on wet soils may lead to increased nitrate leaching (Judson et al. 2010). Thus, there is a need to identify forage system approaches that reduce N excretion in urine.

Some approaches to reduce N excretion in urine include the use of feeds with lower N content such as whole crop barley silage (Kebreab et al. 2001) or feeds containing condensed tannins (CT) (Waghorn et al. 2007). Grazing of forage species such as *Lotus corniculatus* and *Lotus pedunculatus* containing CT has been shown to increased milksolids production and reduce urinary N excretion in dairy cows (Woodward et al. 2009). However, grazing these species may be challenging in winter feeding systems due to their low potential DM yield in winter compared to forages such as kale. Previous work on feeding *Lotus corniculatus* silage to dairy cows during lactation has shown that the CT present in this forage increased milksolids production by 46% (Woodward et al. 2000). Misselbrook et al. (2005) and Powell et al. (2009) have indicated reduced N excretion in urine and increased excretion in faeces when cattle have been fed *Lotus* spp. silage during lactation. This presents an opportunity to grow and conserve *Lotus* spp. as part of the cropping rotation on dairy support land and use it as a supplement to reduce N losses in high risk winter feeding systems.

The objective of this trial was to measure the effect of supplementary feed type on apparent DM intake and N losses in urine and faeces of cows grazing a diet of predominantly kale. The study compared the industry standard feeding regime of kale supplemented with barley straw, to kale supplemented with whole crop barley silage as an example of a low N feed or *Lotus pedunculatus* silage as an example of a CT-containing silage.

Materials and methods

The experiment was conducted between 11 and 25 July 2011 at the Lincoln University, Ashley Dene farm, Lincoln, Canterbury. Kale (cv. *Regal*) was sown in December 2010 and managed with irrigation. Animal sampling procedures were approved by Lincoln University Animal Ethics committee.

Experimental design

Forty non-lactating, pregnant, spring calving Friesian x Jersey cows were blocked according to age (mean 4.8 years, range 2–11 years), calving date (mean 15 August 2011, range 6 August–3 September 2011), body condition score (mean 4.8, range 4.0–6.0) and live weight (mean 514 kg, range 427–646 kg), and randomly assigned to eight groups of five cows. The groups were randomly assigned to two replicates of four treatments in a completely randomised design.

The four treatments were: kale plus barley straw (S); kale plus whole crop barley silage (WCBS); kale plus *Lotus* silage with polyethylene glycol (PEG) (LS+PEG) and kale plus *Lotus* silage without PEG (LS-PEG). Addition of PEG to the *Lotus* silage treatment enabled the effects of condensed tannins (CT) to be determined as PEG inhibits the activity of CT. DM allowance for each treatment was 14 kg DM kale plus 3 kg DM supplement per cow per day. Though metabolisable energy (ME) requirements of late gestation dairy cows are estimated to be around 80–115 MJ ME/cow/d (Nicol & Brookes 2007) previous studies showed an allowance of 14 kg kale DM/cow/d was necessary to ensure cows gained approximately 0.5 units of body condition score over the winter feeding period (Greenwood et al. 2011). Prior to the experimentation period cows had been offered approximately 14 kg DM/cow/d of kale and barley straw since drying-off in late May.

Supplement allocation

Daily supplement allocation was based on feed moisture content. Dry matter was assessed four times during the experiment by recording fresh weight and dry weight after oven drying at 100°C, of a random grab sample. On average, the DM% of the S, WCBS and LS supplements were 80%, 44% and 43%, respectively. At 0900 h each day, the supplement was fed to each group of cows in feeders at the end of each plot. The *Lotus* silage was placed into the feeder in layers, between which dry flakes of PEG were dusted evenly, this ensured the presence of PEG throughout the silage and would enable equal intake among animals. At 1000 h, by which time the groups had finished their supplement they were offered a fresh break of kale. This routine was maintained throughout the experiment. Cows had access to water at all times during the experiment.

Kale allocation

On Day 1 and Day 8, kale DM yield was determined by harvesting material to ground level in four randomly placed 1 m^2 quadrats per plot over a representative grazing area for the coming week. The bulk fresh weight of kale was recorded in the field before three short, medium and tall representative kale plants were taken for DM and chemical analysis. The leaf and stem were analysed separately. The samples were weighed fresh and after oven drying at 100°C for 48 h and the weights recorded. The average bulk fresh weight of each plot and the average DM% across all plots were used for calculating the pre-grazing DM yield (kg DM/ha) and determining the break size of each plot to achieve kale allocation of 14 kg DM/cow/d.

Utilization and apparent intake

Utilisation and daily DM intake were determined by harvesting residual kale on Day 8 and Day 14. In each plot, two 1 m^2 quadrats were taken randomly from breaks that were grazed on Days 3, 5, 7, 10, 12 and 14. All kale including both leaf and stem, within each quadrat was collected. The kale was washed and sorted to remove soil, faeces and dead material. The sample was weighed fresh, oven-dried at 100°C for 48 hours and weighed dry. From this data, DM utilisation (%) was calculated as (Pregraze mass (kg DM per quadrat) – Post graze mass (kg DM per quadrat)) / Pregraze mass (kg DM per quadrat) x 100 and used to estimate apparent intake of kale (kg DM/cow/d) as DM allowance x DM utilization. Daily supplement refusal was also weighed to determine the daily intake of supplement. From this the total daily DM intake of supplement plus kale, was calculated.

Chemical analysis

Freeze-dried subsamples of each supplement and oven-dried leaf and stem samples of kale, were ground to pass through a 1.0 mm sieve (ZM200 rotor mill, Retsch Inc. Newtown, Pennsylvania, USA).

Digestibility of the organic matter in the dry matter (DOMD), crude protein (CP), water soluble carbohydrate (WSC), neutral detergent fibre (NDF) and detergent fibre (ADF) were estimated by near infrared spectroscopy (NIRSystems 5000, Foss, Maryland, USA). Prediction equations were based on separate calibrations for silage and green forage using AOAC (1990) approved wet chemistry procedures ($R^2 > 0.95$). Metabolisable energy (MJ ME/kg DM) was calculated as DOMD (g/100g DM) x 0.16 (Geenty & Rattray 1992). CT in *Lotus* silage were analysed at Massey University, Palmerston North using the butanol-HCL method described by Terill et al. (1992).

Animal sampling

Four days before the trial and on the last sampling day, the cows were weighed and body condition scored. Between 1100 h and 1200 h on Days 9, 11 and 15 faecal and urine spot samples were taken from each animal, when all cows were predominantly grazing kale. Faecal samples were collected by manually stimulating defecation. Urine was collected mid- stream after stimulation by rubbing the vulva by hand, and acidified with sulphuric acid. Faecal and urine samples were stored frozen (-20°C). After thawing, each faecal sample was mixed thoroughly and a subsample of about 20 g was weighed fresh, oven-dried at 100°C and then weighed dry to determine DM%. Another subsample (~30 g) was freeze-dried for five days at 0.5 mbar, ground through a 1 mm grinder and analysed for N% by Elementar (Variomax CN Analyser. Analysensysteme GmbH, Hanau, Germany). Urine samples were thawed at 4°C and analysed for urea, ammonia, N% (Elementar) and creatinine (kinetic colorimetric assay, Roche Creatinine Jaffe kit).

Table 1 Pre- and post- grazing dry matter (DM) yield, DM utilisation and DM intake of kale; supplemented DM intake and total DM intake of the treatment groups supplemented with barley straw (S), whole crop barley silage (WCBS), *Lotus* silage with polyethylene glycol (LS+PEG) or *Lotus* silage without polyethylene glycol (LS-PEG). n = 2.

Parameter	Measurement	Treatment				Least significant difference	P value
		S	WCBS	LS+PEG	LS-PEG		
Kale	Pre-grazing yield (kg DM/ha)	8,694	8,274	7,889	7,789	799	0.10
	Post-grazing yield (kg DM/ha)	1,787	1,324	1,765	1,695	606	0.26
	Utilization (%)	79.6	83.8	77.7	78.3	9.7	0.41
Intake	Kale (kg DM/cow/d)	11.5	12.2	11.3	11.4	1.4	0.42
	Supplement (kg DM/cow/d)	3.0	3.0	3.0	3.0		
	Total (kg DM/cow/d)	14.5	15.2	14.3	14.4	1.4	0.42

Table 2 Chemical composition of kale, barley straw, whole crop barley silage and *Lotus* silage. DOMD = Digestibility of the organic matter in the dry matter; ME = Metabolisable energy; N = Nitrogen; WSC = Water soluble carbohydrate, ADF = Acid detergent fibre; NDF = Neutral detergent fibre. Bolding of P values indicates significance $P < 0.05$.

Component	Kale	Barley straw	Whole crop barley silage	*Lotus* silage	Least significant difference	P value
DOMD (g/100g DM)	85.1^{a}	43.7^{b}	61.6^{b}	68.1^{c}	12.3	**0.003**
ME (MJ ME/kg DM)	13.5^{a}	6.6^{b}	9.9^{c}	9.8^{d}	2.0	**0.003**
N (g/100g DM)	2.2^{b}	0.8^{c}	1.8^{a}	3.3^{d}	0.4	**<0.001**
WSC (g/100g DM)C	41.9^{a}	2.8^{b}	10.6^{b}	5.1^{c}	6.5	**<0.001**
ADF (g/100g DM)	21.0^{d}	49.4^{b}	31.7^{c}	26.7^{a}	6.3	**<0.001**
NDF (g/100g DM)	26.0^{d}	79.5^{b}	54.7^{c}	36.6^{a}	5.6	**<0.001**

Statistical analysis

Daily urinary N excretion (UNE), faecal N excretion (FNE) and nitrogen use efficiency (NUE) were estimated using the following equations:

UNE (g N/d) = LW (kg) x 21.9 (mg/kg) x (1 / Urinary creatinine (mg/kg)) x Urine N% x 10) (Pacheco et al. 2007).

FNE (g N/d) = DM intake (kg DM/cow/d) x (100 - DOMD) x (Faecal N% x 10)

NUE (%) = N excreted (g) / N intake (g) x 100

ANOVA was performed on the group means for intake and N excretion variables across sampling days. Kale yield and chemical composition were analysed on means of combined sampling dates. The general linear model procedure of Genstat (Payne et al. 2009) was used with Treatment as a fixed effect. The model was based on two replicates of four treatments. Means separation ($P < 0.05$) were performed using Fishers protected LSD test.

Results

Chemical composition and intake

Total mean kale DM yield was 8.2 ± 0.2 (Standard error) (t DM/ha) (Table 1) and DM% was 13.7 ± 0.4%. Post grazing residual and DM utilisation of kale did not differ among treatment groups (Table 1). Consequently, there was no difference in apparent DM intake of kale among treatment groups. Supplement contributed approximately 20% of the total diet across all treatments (Table 1). Only cows in the S treatment did not consume 100% of their supplement (Table 1). The chemical composition of the kale and supplements is presented in Table 2. The N content of the feeds was highest in *Lotus* silage, intermediate in whole crop barley silage and kale and lowest in straw. The digestibility and metabolisable energy content of feeds was highest in kale, intermediate in *Lotus* silage and whole crop barley silage and lowest in straw. The CT concentration of the *Lotus* silage DM was 2.7%. The consumption of CT from LS with and without PEG was low at 81 g CT per day which with an average intake of 14.3 kg DM per day equates to 5.6 g CT/kg DM.

Nitrogen intake and excretion

Nitrogen intake from the kale was not significantly different between treatment groups however, differences in the N content of the supplement resulted in differences in total N intake among treatment groups (Table 3). Each cow consumed on average 99.3 g N/cow/day from the supplement in the LS-PEG and LS+PEG treatment groups but only 52.8

Table 3 Nitrogen (N) intake, faecal dry matter and content, urine nitrogen, creatinine, ammonia and urea content, N excretion and N use efficiency (NUE) of cows offered kale, supplemented with whole crop barley silage (WCBS), Lotus silage without PEG (LS-PEG), Lotus silage with PEG (LS+PEG) or barley straw (S). (n = 2). P values in bold indicates significance P < 0.05. P values in italics indicates approaching significance with a P value between 0.05 and 0.10.

Parameter	Measurement	Treatment				Least significant difference	P value
		S	WCBS	LS+PEG	LS-PEG		
N intake	Supplement (g N/cow/d)	23.1	52.8	99.3	99.3		
	Kale (g N/cow/d)	257	270	251	253	31.4	0.42
	Total (g N/cow/d)	280^{b}	323^{a}	350^{a}	352^{a}	31.4	**0.009**
Faeces	Dry matter (%)	16.4	16.2	16.7	16.7	1.67	0.82
	Nitrogen (%)	2.43^{c}	2.74^{bc}	3.05^{ab}	3.28^{a}	0.42	**0.02**
Urine	Nitrogen (%)	0.25	0.27	0.38	0.36	0.14	0.14
	Creatinine (mmol/L)	1.46	1.56	1.82	1.71	1.03	0.78
	Ammonia (mmol/L)	0.55	0.68	0.78	1.04	0.50	0.35
	Urea (mmol/L)	63.9	73.5	100	95.9	56.7	0.18
N excretion	Total (g N/cow/d)	284^{bc}	266^{c}	306^{ab}	324^{a}	30.8	**0.02**
	Faeces (g N/cow/d)	82.3	80.5	79.4	85.8	11.0	0.48
	Urine (g N/cow/d)	202^{bc}	186^{c}	227^{ab}	239^{a}	32.8	**0.04**
Nitrogen use efficiency	Faeces (% of N Intake)	29.5	24.9	22.7	24.4	4.69	*0.06*
	Urine (% of N Intake)	72.1	57.5	64.7	67.9	10.6	*0.07*

and 23.2 g N/cow/day from the WCBS and S treatment groups, respectively. Total N intake for LS-PEG and LS+PEG were similar (352 and 350 g N/cow/day, respectively) and were greater (P<0.05) than WCBS (323 g N/cow/day) and S (280 g N/cow/day).

Urine N% tended to be higher in treatment groups fed LS+PEG and LS-PEG compared to the treatment groups fed S and WCBS (P = 0.14) (Table 3). There were no differences among treatment groups for urine creatinine, ammonia or urea concentrations (Table 3). There were no differences between treatment groups for faecal DM% or faecal N excretion. Faecal N% was higher in treatment groups fed LS+PEG and LS-PEG than those fed S and WCBS. Treatment groups fed LS+PEG and LS-PEG had higher urinary N excretion than those fed kale with WCBS and S (P < 0.05) (Table 3). There was no difference in NUE between treatment groups for excretion in urine and faeces (Table 3).

Mean increase in live weight (18.2 ± 4.0 kg) and body condition score did not differ between treatment groups over the 14 day period.

Discussion

DM utilisation and apparent DM intake

Daily apparent DM intake of kale when offered at 14 kg kale DM/cow/d averaged 11.6 kg DM/cow/d and was unaffected by supplement type, reflecting a similar DM utilisation across treatment groups with a mean of 80%. Similar or higher utilisation on kale has been reported from pre- and post-grazing measurements in a farm survey (Judson & Edwards 2008) and in experimental studies (Greenwood et al. 2011; Rugoho et al 2010). In the current study the relatively high levels of DM utilisation of kale combined with almost complete consumption of supplement gave apparent daily DM intake values ranging from 14.3 to 15.2 kg DM/cow/d. Similar DM intakes were recorded from pre- and post-grazing measurements (Rugoho et al. 2010) and from individual cows using alkane analyses (I. Rugoho, Personal communication) of cows grazing kale at a 14 kg DM/cow/d allowance. While the intake potential of cows grazing kale is recognised as a subject for further investigation (Greenwood et al. 2011), the current results indicate the high potential intake of low NDF forage in late lactation.

N intake and losses

Based on the DM intake values calculated and feed N content, daily N intake ranged from 280 to 352 kg N/cow/d, being highest where *Lotus* silage was fed as a supplement. The two *Lotus* silage treatment groups also had the highest N concentration in the urine and N excretion per day. This confirms the findings of Kebreab et al. (2001) of the general relationship that increasing N intake leads to greater N excretion in urine. The N concentration values for urine are some of the first reported for free ranging cows grazing kale in winter and are low relative to cows grazing pasture (Bryant et al. 2010; Pacheco et al. 2010). This probably reflects in part the low N intake of cows grazing kale (< 258 g N/cow/d) combined with the

high water content of kale (13.3% DM) leading to dilution of urine (Ledgard et al. 2007). It is worth considering the implications of spot sampling and how the samples may not capture the variation in urine N concentration that occurs throughout the day. However samples were taken when cows were grazing kale to reflect the temporal urination pattern whereby cows are most likely to urinate during grazing (Draganova et al. 2010).

Effects of feeding Lotus silage

Previous silage feeding studies (Misselbrook et al. 2005; Powell et al. 2009) have noted that increasing the CT content of the forage legume can result in a shift in N excretion from urine to faeces. In this study, faecal N % was highest where *Lotus* silage was fed as a supplement to kale. However, there was no difference in the calculated partitioning of N into urine and faeces or in total N faecal excretion. Further, there was little detectable difference in any response variable between the LS+PEG and LS-PEG treatment groups, indicating little effect of condensed tannins on partitioning of N. This result may be due to the low CT content (2.7%) of the *Lotus* silage and so the low overall proportion of CT in the diet (5.6 g CT/kg DM). Woodward et al. (2009) showed that by including freshly cut *Lotus* forage at a small proportion (15%) in the diet (equivalent to 0.65% CT), partitioning of N was altered. However, the activity of CT on proteins during fermentation is not well understood. It is feasible that CT did not alter N partitioning due to changes in the proportion of protein bound and free CT during the silo process. Alternatively, the action of CT on the base diet of kale when offered at a high allowance where protein is non-limiting may not be apparent in short duration trials (Barry et al. 1999).

Conclusion

High DM utilisation resulted in high daily DM intakes by dairy cows grazing kale in late pregnancy. The concentration and amount of N excreted in the urine of cows grazing kale in winter were lowest when barley straw was fed with kale, which is a standard feeding regime in the industry, and when whole crop barley silage was fed as a supplement with kale. Introducing a high N supplement such as *Lotus* silage increased the concentration and amount of N excreted in urine, with little evidence that the CT in *Lotus* silage altered partitioning from urine toward faeces.

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