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Grazing behaviour, dry matter intake and urination patterns of dairy cows offered kale or fodder beet in winter

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Abstract

The opportunity to reduce nitrogen (N) losses to the environment from wintering systems for dairy cows may arise from a combination of restricted grazing systems and feeding low N diets to reduce N intake. Lack of information on urination behaviour and grazing intake during restricted grazing makes it difficult to predict animal and environmental responses. Three winter forage systems were simulated and pregnant, non-lactating Friesian x Jersey dairy cows were offered diets which varied in crop allowance and supplement: early sown-kale (EK) comprising 14 and 3 kg DM/cow/d of kale and barley straw; late-sown kale (LK) comprising 11 and 5 kg DM/cow/d of kale and green-chop oat silage; and fodder beet (FB) comprising 8 and 6 kg DM/cow/d fodder beet and grass baleage. Grazing behaviour, DM intake, DM utilisation and urination and faecal frequency, were recorded for six hours following morning crop allocation. After six hours, utilisation of EK, LK and FB crops were 82, 76 and 90%, corresponding to respective DM intake rates of 1.9, 1.4 and 1.2 kg DM/cow/hr. Average urination frequency (2.7 urinations/cow) and duration (9.1 seconds/urination) during the six hour grazing bout was similar for all treatments, and urine N concentration was also similar for each treatment (2.22 g N/L). As cows consumed a high proportion (> 75%) of their daily intake within six hours, and few urination events occurred during this period, the results indicate suitability for use of these systems in a restricted grazing regime combined with a standoff pad in order to mitigate losses of N to environment.

Keywords: *Brassica oleracea;Beta vulgaris*

Introduction

A large proportion of South Island dairy farms winter their pregnant, non-lactating dairy cows off the milking platform, in many cases on local mixed cropping farms. The agricultural systems complement each other by providing cash flow to the cropping farmer and enabling more days in milk and greater productivity on the milking platform. Brassica crops such as kale (*Brassica oleracea* ssp. *acephala*) and fodder beet (*Beta vulgaris* L.) are typically used as the main dietary forages as they fit well in rotational cropping systems, and maintain high diet quality at dry matter (DM) yields exceeding 10 t DM/ha (Judson et al. 2010). Crop residues such as cereal straw or ensiled forages are used to supplement the crop diet to manage ingestive behaviour and provide a source of effective fibre or crude protein (CP) where the crop may be limiting. However, high stocking densities used to harvest the high DM yield (between 10 - 25 t DM/ha) obtained from these crops can result in large nitrogen (N) losses as nitrate leaching from animal excreta during the winter period (Haynes & Williams 1993; Monaghan et al. 2007).

The positive relationship between N intake and urinary N losses is well established (Higgs et al. 2013; Tas et al. 2006), and predictions of N loss are primarily based on N intake. Thus, one strategy to reduce N losses under grazing systems is to reduce N intake by feeding low N-containing crops (Hoekstra et al. 2008). This may be achieved through choice of crops (e.g. fodder beet) and supplements (e.g. straw) of low N content (Miller et al. 2012).

Recent research suggests that while urine events are the major contributor to N leaching, there is large variability in N leaching risk from individual urine patches which is associated with the N concentration and volume of urine deposited in a single event (Li et al. 2012). More information on urination behaviour with respect to the timing of high risk urine events may provide solutions to reduce urination on grazing areas. For example the use of restricted grazing and stand-off pads can be used to capture urine events. Christensen et al. (2012) found reductions in N loss as nitrate of over 30% when cows were restricted to 4 hours grazing on pasture.

Ultimately, managing N losses will be a combination of factors, and farmers may be faced with decisions regarding large system changes to manage N losses. Accurate predictions of N losses in response to management changes requires knowledge of where reductions in N loss can be made without compromising the targets of maintaining high DM utilisation of crops and consuming sufficient forage to meet the energy requirements of livestock. The objective of this study was to measure DM utilisation and intake, grazing behaviour and urination patterns of dairy cows grazing fodder beet and high (early-sown) and low (late-sown) DM yielding kale crops. This was conducted with the objective of developing the baseline information necessary for incorporating restricted grazing into winter grazing systems.

Materials and Methods

Experimental site and treatments

The experiment was conducted at Ashley Dene, Lincoln, Canterbury (-43.65 ^{o}N 172.33 ^{o}E) with the approval of the Lincoln University Animal Ethics Committee (AEC 523). Three un-replicated winter-grazing systems were compared between 26 June and 5 July 2013. The crops used in each system consisted of kale (cultivar Regal) sown early on 18 October 2012 or late on 10 December 2012 and fodder beet (cultivar Rivage) sown 29 October 2012. Early-sown kale was fed at an allowance of 14 kg DM/cow/d, supplemented with barley straw (3 kg DM/cow/d) (EK). Late-sown kale was fed at 11 kg DM/cow/d, supplemented with green-chop oat silage at 5 kg DM/cow/d (LK). Fodder beet was fed at 8 kg DM/cow/d, supplemented with ryegrass baleage at 6 kg DM/cow/d (FB). Supplements were fed daily at 0700 h and followed by crop allocation at 0900 h. Cows were strip grazed within each block with the size of the allocation determined by measurements of pre-grazing crop DM yield (Miller et al. 2012). The supplements were chosen as representative of industry practises with forage crops. Barley straw, a low N supplement, is typically fed with kale in wintering systems. Grass baleage, a moderate N supplement, is often fed with fodder beet to raise the overall N content of the diet associated with feeding fodder beet of low N content. Oat silage was fed with the late kale, to reflect that in this system, it is grown in rotation with kale in a crop sequence; oats were sown as soon as the kale is grazed in previous winter, and harvested as green chop silage in early summer, before the second kale crop was sown. The combination of crop and supplement diet was designed to be isoenergetic, supplying 160 MJ ME/cow/day.

Experimental design

A total of 150 pregnant, non-lactating, spring-calving Friesian x Jersey dairy cows were divided into three herds of 50 cows according to calving date (26 August 2013 ± 15.2 d), live weight (501 ± 49.4 kg LW), age (4 ± 1.8 year) and breeding worth (122 ± 33.6 BW), and randomly assigned to graze one of the three crops from 29 May 2013 to 31 July 2013. Cows were transitioned on to the crops over a period of 11 days, increasing the crop offered by 0.5-2 kg DM each day and offering pasture for the remainder of the period. Cows were offered a new allocation each day, with grazing areas separated by electric fencing.

Animal measurements

On three occasions (25 June, 3 and 5 July 2013), the grazing, ruminating, idling and urination (number and duration of event) behaviour of five cows was recorded every 5 minutes by visual observation of trained observers between 0900 and 1500 h. To maintain visibility of cows on tall kale crops (1.5 – 2.0 m height), the number of cows observed was restricted to five animals, with the five cows separated into a smaller grazing area offered at the same crop and supplement allowance as the remainder of the cows. On each date, five new cows were randomly selected from the herd of 50. Spot samples of urine and faeces were collected on 4 July 2013 from 15 cows in each treatment. Urine and faecal samples were collected and analysed for N% and DM% as described by Miller et al. (2012).

Diet measurements

Dry matter yield was determined before and after offering a fresh break from quadrat cuts (1 m^2, n= 6) for EK and LK and from 2-m row lengths for FB (n= 6) within the smaller grazing area. Plants were separated into leaf and stem or bulb, weighed and separated into two subsamples. One subsample was oven dried at 65°C for determination of DM%. The second subsample of crop, and a subsample of each supplement was freeze-dried, ground to 1 mm, and scanned by near infra-red spectrophotometer (NIRS, NIRSystems 5000, Foss, Maryland, USA) to predict chemical composition and concentration of digestible organic matter in DM (DOMD). Metabolisable energy (ME) was calculated as MJ ME/kg DM = 0.16 x DOMD (CSIRO, 2007). Apparent DM intake was calculated from herbage disappearance between pre- and post-grazing at 6 and 24 h after crop allocation.

Statistical analysis

The effect of crop type on behaviour variables were analysed by one-way ANOVA with dates as blocks (n=3), cows as replicates (n=5) and crops as fixed treatments (GenStat 15.1 VSN International LTD. 2012). Urine and faecal N concentrations and faecal DM% were analysed by one-way ANOVA using cows as replicates (n=15) and crops as fixed effects. Non-normally distributed data were transformed prior to ANOVA, and untransformed means presented. Where ANOVA was significant ($P < 0.05$), a Tukey test was used to separate means.

Results

Diet analysis

The mean ratio of leaf to stem (± SEM) was 0.39 ± 0.08, 0.71 ± 0.17 and 0.17 ± 0.01 for EK, LK and FB, respectively. The two kale crops had similar chemical composition, with forage CP not exceeding 14% of DM for any of the crops and lowest for FB at less than 10.9% of DM (Table 1). Metabolisable energy content was greater for EK and LK than FB, due to greater DOMD of kale crops. Barley straw had lower CP and ME than oat silage or ryegrass baleage (Table 1).

Grazing behaviour

Pre-grazing crop yield was greater in FB than EK or LK (Table 2). Crop DM utilisation in the first six hours was, on average, 83% across the three treatments, but did not differ between forage crops. The DM intake of crop over the first six hours was greater ($P < 0.01$) on EK than LK or FB and the

Table 1 Chemical composition (% of DM) and metabolisable energy content (MJ ME kg/DM) for pre-grazing samples of early-sown kale (EK), late-sown kale (LK) and fodder beet (FB), and for barley straw (BS), green chop oat silage (GCOS) and ryegrass baleage (RB) supplements. Analysis of crops was based on the whole plant sample combining leaf, stem and bulb.

Parameters[1]	**Crop**			**Supplement**		
	EK	**LK**	**FB**	**BS**	**GCOS**	**RB**
DM %	11.5	11.9	14.0	89.5	37.1	58.0
CP	13.8	13.4	10.9	5.1	16.1	11.6
SSS	45.3	44.6	71.5	3.1	13.0	28.3
ADF	20.9	19.6	10.4	45.9	30.4	23.6
NDF	26.7	23.1	17.1	78.8	52.0	44.1
Ash	8.7	9.1	7.5	11.0	9.2	7.2
DOMD	81.7	84.4	80.3	38.5	63.6	76.4
ME	13.1	13.5	12.8	6.2	10.2	12.3

[1]CP= crude protein; SSS= starch and soluble sugars; ADF= acid detergent fibre; NDF= neutral detergent fibre; ME= metabolisable energy; DM= dry matter; DOMD= digestible organic matter in the DM.

variation in time spent grazing for each treatment resulted in respective crop intake rates of 43.7, 32.8 and 45.9 g DM/minute. Cows spent more ($P < 0.01$) time grazing but less ($P < 0.01$) time idling on EK and LK than FB (Table 2). Cows on EK and FB spent relatively more time eating stem or bulb. There was an average of 2.7 urinations per cow in the first six hours of grazing, with urinations tending ($P = 0.08$) to be more frequent on LK and FB than EK. (Table 2). The duration of mainstream urination averaged 9.2 seconds and was similar across treatments.

After 24 hours, crop DM utilisation was lower ($P < 0.05$) in EK (87%) and LK (88%) than FB (97%) (Table 3). Nitrogen intake over 24 hours from the forage crop was lower on FB and LK than EK, with total N intake ranging from 228 g N/cow/d for FB to 296 g N/cow/d for LK (Table 3). Faecal (21 g N/kg DM) and urinary (2.2 g N/L) N concentrations were

Table 2 Crop DM yield (t DM/ha), DM utilisation (%), apparent DM intake (kg DM/cow/d) grazing behaviour (minutes) and urination and faecal behaviour six hours after allocation of forage crops to dairy cows grazing early-sown kale (EK), late-sown kale (LK) and fodder beet (FB).

	Crop			**SED**[1]	**P value**
	EK	**LK**	**FB**		
Utilisation					
Pre-grazing DM yield	12.5[b]	10.1[b]	19.2[a]	1.5	<0.001
Post-grazing DM yield	2.2	2.4	1.9	0.8	0.844
DM utilisation	82.4	76.2	90.1	6.4	0.217
Apparent crop DM intake	11.5[a]	8.4[b]	7.2[b]	0.7	0.009
Grazing behaviour					
Grazing leaf	63[b]	125[a]	22[c]	0.5	<0.001
Grazing stem	201[a]	131[b]	135[b]	13.7	<0.001
Total time grazing	263[a]	121[c]	157[b]	14.0	<0.001
Eating supplement	12[b]	11[b]	30[a]	6.2	0.005
Idling	54[b]	48[b]	140[a]	11.7	<0.001
Ruminating	16	10	22	5.7	0.106
Sitting	27[ab]	7[b]	37[a]	9.5	0.009
Standing	298[b]	322[a]	290[b]	9.9	0.008
Urination behaviour					
Urination duration (sec)	9.4	9.2	8.9	1.3	0.935
Total urination events	2.0	3.1	2.9	0.5	0.078
Total faecal events	1.7[a]	1.5[a]	2.9[b]	0.5	0.005

[1]Standard error of the difference. Means within a row with different superscripts are significantly different according to Tukey test ($P < 0.05$).

Table 3 Crop DM yield (t DM/ha), daily DM utilisation (%), apparent DM intake (kg DM/cow/d), N intake (g N/cow/d) and urine and faecal N and DM concentrations from spot samples for dairy cows grazing early sown kale (EK), late sown kale (LK) and fodder beet (FB) 24 hours after allocation.

	Crop			SED[1]	P value
	EK	LK	FB		
Dry matter utilisation					
Post grazing yield	1.6[a]	1.3[a]	0.5[b]	0.3	0.05
DM utilisation	87.0[b]	87.6[b]	97.2[a]	2.5	0.027
Apparent crop DM intake	12.2[a]	9.6[b]	7.8[c]	0.3	<0.001
Apparent total DM intake	13.7	13.1	12.8	-	-
Nitrogen utilisation					
Apparent crop N intake	269[a]	207[b]	136[c]	7.4	<0.001
Apparent total N intake	281	296	228	-	-
Urine N concentration (g/L)	2.44	2.01	2.23	0.45	0.77
Faecal N concentration (% DM)	2.19	2.01	2.09	0.12	0.27
Faecal DM%	17.2	18.9	23.0	2.48	0.07

[1]Standard error of the difference. Means within a row with different superscripts are significantly different according to Tukey test ($P < 0.05$).

low, and were not affected by treatment. Faecal DM% tended to be greater ($P = 0.07$) for FB than EK and LK (Table 3).

Discussion

Intake rates on all forages were high, and within six hours of being offered a fresh break, cows had consumed 82% (EK), 76% (LK) and 90% (FB) of their total daily DM intake. These corresponded to DM intakes of 11.5, 8.4 and 7.2 kg DM/cow for EK, LK and FB, respectively. The high DM intake rates of kale are consistent with those reported by Rugoho et al. (2010; 2014). The high DM intakes are also consistent with previous work with lactating dairy cows grazing pasture. Dobos et al. (2009) reported that > 70% of daily intake of perennial ryegrass was achieved in the first four hours after offering a fresh break, while Gregorini et al. (2009) showed that cows offered pasture once a day consumed 10 kg DM/cow after 3 hours of grazing. Little comparable data is available on intake rate of fodder beet, where bulbs have to be extracted from the ground; however, intake rates observed for FB, are consistent with those of Thompson & Stevens (2012), who reported cows consumed 4.8 kg DM of swede, a bulb-forming plant similar to fodder beet, over 5 hours.

Intake over the first six hours was lower in FB than EK and LK. This probably reflects the low overall allowance of forage crop of FB (8 kg DM) than EK (14 kg DM) and LK (11 kg DM), which is likely to have restricted intake. When apparent DM intake is adjusted for percent of total crop consumed, there is little difference between rate of utilisation for LK, FB and EK (88, 92 and 94% respectively) in the first six hours. Thompson & Stevens (2012) reported lower intake rates from cows grazing swede compared with kale and attributed this to difficulty removing bulbs from the ground. Bulb extraction did not appear to a problem in the present study as calculated intake rates in the first six hours were similar on EK (44 g DM/min) and FB (46 g DM/min). Rather the increased proportion of leaf in the LK crop appeared to have reduced intake rate of cows on this treatment (33 g DM/min) as cows spent a greater proportion of their grazing time (52%) eating leaf compared with cows on EK and FB (< 25% of their grazing time).

Nitrogen intake was highest on LK followed by EK, and FB crop systems (296, 281 and 228 g N cow/d, respectively). Nitrogen were comparatively lower than the values of over 300 g N/cow/d previously reported by Rugoho et al. (2010) and Miller et al. (2012) using similar wintering treatments. Similarly, N intakes in the current study are also considerably lower than the reported values of 400 – 600 g N/cow/d for pasture-fed cows during early (Bryant et al. 2013) and late (Totty et al. 2013) lactation. The low total N intake is likely to have contributed to a low overall N concentration of urine (2.2 g N/L) in all forage crops relative to data from cows grazing pasture (Bryant et al. 2013). Among the three systems the role of supplements was to either maintain N intake at close to 300 g N/day, as with the kale crops, or increase N intake as with fodder beet. However, the CP concentration of the ryegrass baleage was relatively low at less than 12% of the DM and N intakes on this system were less than 250 g N/cow/day. As N intake is a key predictor of N excretion in urine (Higgs et al. 2012), N excretion per day on these feeding systems would also be expected to be low (see also Miller et al. 2012). The low N excretion predicted may make it challenging to reduce N excretion further through dietary manipulations (Miller et al. 2012) and may negatively affect cow performance due to restricted metabolisable protein (MP) supply. Use of benchmark values for N intake to meet MP requirements, incorporated with restricted grazing regimes and stand-off pads, presents tools for farmers to manage animal performance and environmental consequences of grazing high yielding crops.

Given the high water intakes of between 50 (FB) and 100 (EK) litres, from these low DM crops it was expected that frequency and volumes of urine events during the main grazing bout would be large. However these results showed very few urination events occurred during the six hour grazing period following crop allocation, and little difference in urination behaviour across forage crops. On average cows urinated fewer than three times during the six hour observation period (2.7 urinations/cow), with a urination duration of less than 10 seconds per event. The duration of urination was taken as a proxy for urine volume, assuming similar flow rates, although more data is needed on variation in flow rate to be confident of such assertions. Betteridge et al. (2013), using urine harnesses to record volume and frequency of urination from free-ranging cattle, reported the largest urine events occurred at night and early in the morning. Further, previous estimates indicated pasture-fed dairy cows urinated approximately 14 times per day (McLeod et al. 2009; Draganova et al. 2010). Thus, use of stand-off pads, as described by Christensen et al. (2013), present an opportunity to capture the majority of urination events outside of a six hour restricted grazing period and markedly reduce N leaching from urine patches.

Conclusion

The high DM crop utilisation and DM intake during six hours, combined with the fact that few urinations occurred on the crop during this period, may allow for the use of stand-off pads, while still utilising the benefits of *in situ* feeding of high yielding crops that may be difficult to harvest. This could allow N manure to be captured in effluent systems and returned to the environment in a more controlled manner.

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