The effects of feeding maize silage at different times prior to a herbage meal on dry matter intake, milksolids production and nitrogen excretion in late-lactation dairy cows

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Abstract

The objective of this study was to determine the effect of feeding maize silage at different times before the herbage meal on dry matter (DM) intake, milksolids (MS) production and nitrogen (N) excretion of late lactation dairy cows. In an indoor study, nine Friesian × Jersey dairy cows were assigned to three treatments: (1) herbage only (control); (2) supplemented with 3 kg DM of maize silage after morning milking approximately nine hours before the herbage meal (9BH); and (3) supplemented with 3 kg DM of maize silage after afternoon milking approximately one hour before the herbage meal (1BH). Cows were offered *ad libitum* cut herbage (perennial ryegrass-white clover) for five hours from 1530 to 2030 h. Herbage DM intake was greater (P=0.03) for control than 1BH cows, but did not differ between control and 9BH or between 1BH and 9BH cows (13.71, 11.96 and 12.74 kg DM/cow/day for control, 1BH and 9BH, respectively). The substitution of herbage by maize silage was greater (P=0.05) for 1BH than 9BH cows (0.56 vs 0.31 kg DM herbage per kg DM maize silage, respectively). Milksolids production did not differ between treatments (overall mean 1.33 kg MS/cow/day). Nitrogen concentration in faeces and estimated urinary-N excretion (g/day) were lower in supplemented than control cows. Under herbage restriction, it is important to consider time of maize silage supplementation relative to the herbage meal for managing substitution rate and urinary-N excretion.

Keywords: herbage; maize silage; time of supplementation; urine nitrogen

Introduction

The pasture-based milk-production system in New Zealand is a key contributor to nitrous oxide emission and nitrate leaching, mainly through urinary-N excretion of grazing cows (Di & Cameron 2002). Well-managed New Zealand pasture with a typical combination of perennial ryegrass and white clover is characterized by high N content (3.2 to 4.8%), of which 80% is potentially degradable in the rumen (Clark & Woodward 2007). This high-N diet offers N in excess of requirements for milk production, and can result in inefficient use of intake N and high N loss to the environment through urinary-N excretion. Pacheco & Waghorn (2008) reported that for ruminants grazing good quality pasture, more than 50% of ingested N is excreted in the urine.

Reducing the time cows have access to pasture is one strategy suggested to reduce urinary-N deposition into the pasture (Gregorini et al. 2010). Cows are able to manipulate foraging behaviour, to increase herbage dry matter (DM) intake rate, to compensate for limited access to the pasture (Chilibroste et al. 2007). However, acute restricted grazing (e.g., four hours accesses to herbage) can reduce daily herbage DM intake and alter the efficiency of rumen digestion (Gregorini et al. 2008). Supplementation with other forages can increase total DM intake, and thereby, reduce the impact of herbage feed restriction.

Another tactic to reduce urinary-N excretion is to reduce N intake by feeding cows a low-N supplement such as maize silage (Valk 1994). Further, shifting the time of supplementation (energy source) relative to the herbage meal (N source) was suggested to improve the capture of ruminal ammonia N and hence, reduce urinary-N losses (Gregorini et al. 2010, Mitani et al. 2005). The usefulness of combining different strategies (feed restriction, low N supplement and time of supplementation) on reducing urinary-N excretion still needs to be addressed. In addition, there remains a lack of information regarding how time of supplementation affects substitution rate (SR) and milksolids (MS) in dairy cows subjected to feed restriction strategy.

The objective of the current study was to study the effect of maize silage and time of maize silage supplementation on DM intake, milk production and urinary-N excretion in dairy cows subjected to feed restriction strategy.

Materials and methods

The experiment was conducted using late lactation dairy cows over a period of 27 days (17 April to 14 May 2012) at the Lincoln University Research Dairy Farm, Lincoln, New Zealand (43º 38'S, 172º 27'E). All procedures were approved by the Lincoln University Animal Ethics Committee (AEC # 465).

Experimental design

Nine Friesian × Jersey dairy cows were ranked based on their MS production (1.3 ± 0.11 kg MS/day; Mean ± SD), live weight (LW; 507 ± 19.9 kg), days in milk (253 ±12.9) and body condition score (3.8 ± 0.22; 1 -10 scale). Groups of three animals with similar scores were then randomly assigned to one of three treatments: (1) herbage only, without maize silage (control); (2) supplemented with 3 kg DM of maize silage after morning milking approximately nine hours before the herbage meal (9BH); and (3) supplemented with 3 kg DM of maize silage after afternoon milking approximately one hour before the herbage meal (1BH).

All cows were offered *ad libitum* a cut-herbage mixture of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) over a period of five hours from 1530 to 2030 h. During the experimental period, cows were milked twice a day (0630 and 1420 h) and maintained on a standoff area consisting of a harrowed paddock with no access to vegetation but *ad libitum* access to water.

Cows were maintained on the first treatments for 10 days (day 1-10) and then given a wash out period of seven days (day 11-17) when they were returned to ryegrass-white clover pasture and fed *ad libitum*. After this, each cow was assigned to one of the two remaining treatments for a further period of 10 days (day 18-27).

This designation of treatments resulted in an incomplete cross over design with two periods, with all three treatments replicated six times. All six of the possible two-way sequences were represented in the experiment, although these could not be equally replicated due to there being nine animals in total.

Feeding regime

A mixture of perennial ryegrass and white clover pasture was fertilized with 30 kg of N/ha as urea four weeks before the start of the experiment. Herbage at 4 weeks regrowth was cut to 5 cm above ground level at 1300 h daily and transferred to the barn for feeding. Herbage and maize silage were weighed and offered individually to cows in feeding bins indoors. Feed refusals were measured after the end of each meal.

Sampling and chemical analysis

Two samples each of herbage and maize silage (approximately 100 g fresh weight) were collected daily at 1400 h. One of the samples was immediately oven dried at 60°C for 48 h to determine DM percentage. The second sample was stored at -20°C and later freeze-dried for chemical analysis. Maize silage and herbage sub-samples were ground through a 1-mm sieve (ZM200, Retsch). Chemical composition was estimated using near-infrared spectroscopy (Feed and Forage Analyser, FOSS Analytical, Hilleroed, Denmark). Metabolizable energy (ME) of feed was estimated based on the equation [ME (MJ/kg) = Digestible organic matter content (g/kg DM) × 0.016]; (McDonald et al. 2002). The starch content of the maize silage was estimated using the Megazyme assay procedure K-TSTA 04/2009 (Megazyme International, Bray, Ireland). Nutritive composition of the herbage and maize silage are presented in Table 1.

Milk yield (kg/day) was recorded at each milking (DeLaval Alpro Herd Management System, DeLaval, Tumba, Sweden). Milk sub-samples were collected during both morning and afternoon milking on day 10 and 27 (the last day of each experimental period) using an automatic sampling system. One sub-sample was analysed for milk fat, protein and lactose concentration (Livestock Improvement Corporation, Christchurch, New Zealand) by Milkoscan (Foss Electric, Hillerod, Denmark). A second sub-sample was collected for milk urea N (MUN) analysis. The MUN concentration was determined using an automated Modular P analyser (Roche Hitachi, Basel, Switzerland) as previously described (Talke & Schubert 1965).

Faeces and urine samples were collected after morning milking (before maize silage was offered to 9BH) at 0700 h, at 1300 h, after afternoon milking (before maize silage was offered to 1BH) at 1500 h, and straight after the herbage feeding (2030 h), on day 10 and 27. Samples were collected during voluntary excretion or manual stimulation. Urine was acidified to a pH < 4 to prevent volatilization. All samples were then stored at -20°C until sub-sampled. After thawing, a faecal sub-sample (approximately 50 g) was freeze-dried (supplier; Cuddon Limited, New Zealand Model E. D. 5.3), ground through a 1-mm sieve (ZM200, Retsch) and then analysed for N concentration by Variomax CN analyser (Elementar Analysensysteme GmbH; Germany). The fresh weight of the remainder of the sample was determined and then oven dried at 100°C for 48 h to determine the DM%. Thawed urine samples were analysed for urine ammonia, creatinine, urea concentration and total N% as per kit instructions (Randox Rx Daytona, Randox Laboratories Ltd., Crumlin, United Kingdom). Urinary-N excretion was estimated using three different equations: (1) urinary-N (g/d) = (21.9 (mg/kg) x LW (kg) x (1/urinary creatinine (mg/kg))) x urine N (g/kg) (creatinine-based equation; Pacheco et al. 2007), (2) urinary-N (g/d) = 0.026 x LW (kg) x milk urea N (mg/dl) (MUN-based equation; Kauffman & St-Pierre 2001), (3) urinary-N (g/d) = 1.3 x LW (kg) x plasma urea N (g/l) (PUN-based equation; Kohn et al. 2005).

Blood samples were collected, via coccygeal vein, after morning (before maize silage was offered for 9BH) at 0700 h, after afternoon milking (before maize silage was offered for 1BH) at 1500, and straight after the herbage feeding (2030 h), on day 10 and 27. Blood samples were collected in K_3EDTA-coated vacuettes for plasma collection and analysis. Blood samples were placed on ice immediately after collection and later centrifuged at 3000 x *g* for 10 min at 4°C. Plasma was collected into clean tubes then stored at -20°C. Plasma samples were thawed at 4°C and analysed for plasma urea N (PUN) concentration using enzymatic kinetic method (UR 3825).

Statistical analyses

All statistical analyses were conducted using GenStat 15 (Lawes Agricultural Trust, Rothamsted, UK). The effects of the three treatments on feed intake, MS production, urine, faecal and plasma measurements were analysed using ANOVA which included an incomplete blocking structure (individual cows and two experimental periods). Significance differences between treatment means were identified using protected least significant differences (LSD) ($P < 0.05$) following a significant ANOVA result.

Results

Herbage DM intake was higher for the control than 1BH (P=0.03), but did not differ between 9BH and control or between 1BH and 9BH (Table 2). Total DM intake was increased by supplementation, but was unaffected by time of supplementation. Substitution rate was higher (P=0.05; Table 2) for 1BH than 9BH. In this trial, there was no evidence that supplementation or time of supplementation had an effect on milk production and composition (Table 2).

Table 1 Dry matter (g/kg), chemical composition (g/kg DM), and ME (MJ/kg DM) of herbage and maize silage fed to dairy cows.

Item	Herbage	Maize silage
Dry matter (DM)	203	406
Acid detergent fibre (ADF)	228	290
Neutral detergent fibre (NDF)	397	500
Crude protein (CP)	157	85
Organic matter (OM)	918	961
Organic matter digestibility (OMD)	871	676
Dry matter digestibility (DMD)	818	637
Starch	-	200
Water soluble carbohydrate (WSC)	179	-
Metabolisable energy (ME)	12.9	10.0

Table 2 Dry matter intake, substitution rate (SR), and milk production and composition for dairy cows fed herbage only (Control) or herbage with maize silage either at nine (9BH) or one hour (1BH) before *ad libitum* herbage meal over five hours.

	Treatments				
Item	Control	1BH	9BH	P	LSD[1]
Intake					
Herbage (kg DM/day)	13.71[a]	11.96[b]	12.74[ab]	0.03	1.23
Maize silage (kg DM/day)	-	3.13	3.13		
Total intake (kg DM/day)	13.71[a]	15.09[b]	15.9[b]	0.01	1.24
SR	-	0.56	0.31	0.05	0.26
Milk					
Yield (kg/day)	12.5	12.4	13.5	0.52	3.08
Milksolids (kg/day)	1.27	1.30	1.41	0.31	0.21
Fat %	6.04	6.29	6.23	0.89	1.21
Protein %	4.33	4.49	4.35	0.78	0.55
Fat (kg/day)	0.74	0.76	0.82	0.22	0.11
Protein (kg/day)	0.53	0.54	0.59	0.54	0.11

Treatments with different letters within a row are significantly different (P<0.05). [1]Least significant difference of treatment means when α=0.05.

Nitrogen intake and N parameters are presented in Table 3. Concentration of urea N in milk (P=0.004) and plasma (P=0.05) were lower for supplemented than control cows, but did not differ between 1BH and 9BH. The faecal-N concentration was lower (P=0.001) for supplemented than control cows, but was unaffected by time of supplementation. Urine urea concentration was higher (P=0.037) for control than 1BH, but did not differ between control and 9BH or 1BH and 9BH. Estimated urine N output (g/day) was lower (P=0.005) for 1BH than control and 9BH, but similar between control and 9BH when urine N output was calculated using the creatinine-based equation. Estimated urinary-N output was lower (P=0.021) for 1BH than control, but did not differ between control and 9BH or 1BH and 9BH when urine N output was calculated using the MUN-based equation. When urinary-N output was calculated using the PUN-based equation, estimated urine N output (g/day) was higher (P=0.042) for supplemented than control cows, but did not differ between 1BH and 9BH.

Table 3 Nitrogen intake, and N parameters pertaining to partitioning in milk, plasma, faeces and urine for dairy cows fed herbage only (Control) or herbage with maize silage either at nine (9BH) or one hour (1BH) before *ad libitum* herbage meal over five hours.

	Treatment				
Item	Control	1BH	9BH	P	LSD[1]
Total N intake (g/day)	342	343	362	0.363	32.4
Milk					
Urea N (mmol/l)	5.35[a]	3.96[b]	4.62[b]	0.004	0.69
N output (g/d)	89.9	92.0	98.8	0.556	19.0
Milk N: total N intake (%)	26.1	26.9	27.3	0.885	5.50
Plasma					
Urea N (mmol/l)	8.49[a]	7.35[b]	7.40[b]	0.05	1.00
Faeces					
N%	3.7[a]	3.3[b]	3.4[b]	0.001	0.184
Urine					
Creatinine (mmol/l)	3.55	3.83	3.47	0.751	1.09
N%	0.51	0.44	0.48	0.356	0.111
NH_3 (mmol/l)	0.66	0.59	0.31	0.115	0.353
Urea (mmol/l)	113.9[a]	90.3[b]	99.4[ab]	0.037	17.3
Urinary N output (g/d)					
Calculated using creatinine	154.5[a]	129.6[b]	148.6[a]	0.005	13.0
Calculated using milk urea N	197.2[a]	144.8[b]	169.9[ab]	0.021	33.5
Calculated using plasma urea N	156.1[a]	134.8[b]	135.3[b]	0.042	18.02

Treatments with different letters within a row are significantly different (P<0.05). [1]Least significant difference of treatment means when α=0.05.

Discussion

Dry matter intake and SR

Herbage DM intake was lower for 1BH than control, but did not significantly differ between control and 9BH. This result reflected a lower substitution of herbage when maize silage was supplemented at nine rather than one hour before intensive herbage meal (0.31 vs 0.56 kg DM herbage per kg DM maize silage, respectively). This is in agreement with the result of Hess et al. (2002) who showed higher SR for steers continually grazed pasture and supplemented with corn grain (0.3% of BW) in the afternoon (1800 h) than those supplemented with the same amount but in the morning (0600 h). The difference in SR between 1BH and 9BH may be explained by the rumen-fill constraints resulting from feeding maize silage just before the herbage meal for 1BH.

Milksolids production and composition

In this trial, there was no evidence that supplementation or time of supplementation influenced milk production or milk compositions of cows. The sample size of six measurements per treatment could be considered small when comparing milk production measures in dairy cows, given the high variation that can occur in these metrics. However, in this study the magnitude of the differences between the means for the treatment groups were small (12% or less for all of the variables measured) and all less than one standard deviation (pooled estimate).

The lack of response in milk parameters occurred despite total DM intake being greater for supplemented than control, and SR lower for 9BH than 1BH. However, the CP contents of the three diets were similar (15, 14.2 and 14.2% for control, 1BH and 9BH, respectively), which may have capped milk production. Metabolisable protein (MP) requirements were estimated using calculations from AFRC (1993), and Brookes and Nicol (2007). Calculated CP requirements for milk production and live weight were 2.24 kg/day for supplemented cows supplying 1.07 kg of MP per cow per day. These values were close to the actual CP intake of 2.2, and confirms that MP intake may have been limiting MS response in the current study. The low CP content of herbage may be because of build-up of dead material prior to harvest, high weed content in the sward, and time since N fertilizer application.

Nitrogen excretion

Faecal-N concentration was reduced with maize silage supplementation. This is in agreement with Carlier & Verbruggen (1996) who reported a reduction in faecal-N content (g/kg DM) in cows grazing pasture during the day and supplemented with 5.3 kg DM of maize silage during the night, compared with those grazing solely pasture during the day and night. This reduction in faecal-N concentration by maize silage supplementation may be explained by the higher dilution rate in the faeces of supplemented cows compared with control cows. For control cows with a total DM intake of 13.7 kg DM/cow/day and diet digestibility of 87.2%, calculated faeces volume would be 1.75 kg DM/cow/day. From this and an N intake of 342 g N/cow/day, the calculated ratio of N intake to faeces volume is 0.2 g of N intake per g of faeces. This value is higher than the 0.133 and 0.135 g of N intake per g of faeces for 1BH and 9BH, respectively.

Urinary-N concentration was unaffected by maize silage supplementation. However, estimated urinary-N output was higher for control than 1BH and 9BH when urine N output was calculated using PUN; higher for control than 1BH when urine N output was calculated using creatinine or MUN. These results were supported by higher urea N concentrations in milk and plasma for control than supplemented cows. Valk (1994) reported that feeding maize silage to grazing dairy cows can improve N utilization and reduce urinary-N deposition to the pasture by reducing N intake. However, in this study substitution did occur, but the increased overall DM intake counteracted the effect of maize silage supplementation, leading to similar N intake (342, 343 and 362 g N/cow/day for control, 1BH, and 9BH), and hence, a small effect on urinary-N excretion. Therefore, the reason for the relative reduction in estimated urinary-N excretion of supplemented cows may be related to the better utilization of ruminal ammonia N and the relatively higher ME to CP intake ratio (Holden et al. 1995; Valk 1994) for supplemented than control cows (87 vs 82 MJ ME per kg CP, respectively).

Absolute values of estimated urinary-N excretion were different according to the parameter used to calculate the estimate, but the rankings of urinary-N excretion calculated by different methods were similar. The possible reduction in urinary-N excretion for 1BH compared to 9BH may be explained by N intake, which was marginally higher for 9BH than 1BH (362 and 343 g of N/day, respectively). Nitrogen excretion is known to be sensitive to small changes in N intake, particularly at a high level of N intake/day (Castillo et al. 2000). Based on the prediction equation from Castillo et al. (2000), the 20 g/day increase in N intake between 9BH and 1BH would increase N excretion by 11 g/d for urine. This value is slightly lower than actual value of 19 g/day when urine N output was estimated using creatinine.

Conclusions

Under an herbage feed restriction strategy, feeding maize silage at nine hours rather than one hour before the herbage meal reduced the substitution of herbage by maize silage. In comparison with herbage only, feeding maize silage reduced urinary-N excretion. Time of maize silage supplementation relative to the herbage meal is an important consideration for managing urinary-N excretion, in which feeding maize silage at one hour rather than nine hours before the herbage meal reduced urinary-N excretion.

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