Effect of farm system and milk urea phenotype on milk yield and milk composition of dairy cows in Canterbury

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Abstract

To investigate the effect of farm system, and cow selection for milk urea nitrogen (MUN), on milk yield and milk composition, a farmlet study was carried out between October 2018 and May 2019 in Lincoln, Canterbury. A farm system with a low stocking rate and low N fertiliser input (LSR, 2.9 cows/ha) sown with a conventional ryegrass clover and plantain diverse pastures was compared with a farm system with a moderate stocking rate and moderate N fertiliser (MSR, 3.9 cows/ha) using conventional ryegrass and white clover pastures and supplementing 3 kg DM/cow/d as crushed barley grain. Each farmlet had total herd size of 40 mixed-age HF x J spring-calving dairy cows which included six cows selected solely for a high MUN or a low MUN. There was no effect of farm system on milk fat, protein or lactose content but MUN was lower in LSR compared with MSR. Milk production was also lower for LSR (466 *vs* 429±12.4 kg MS/cow/ha, $P<0.05$), owing to poorer quality diet in mid lactation. Cows selected for low MUN tended to produce less milk compared with high MUN cows (4478 *vs* 3987±174 kg/cow, $P<0.10$) though this was partially offset by increased protein content in milk of low MUN cows. Farm system and animal selection for MUN have a greater impact on milk yield than on milk composition.

Keywords: *Plantago lanceolata*; somatic cell count; multi-species pastures;

Introduction

To meet requirements to reduce nitrogen (N) losses from intensive dairy farming systems, farmers will be expected to adopt a range of mitigation strategies. Because risk of N leaching is driven by both farm N surplus and the distribution or deposition of that surplus through urination events, many of the mitigation options proposed relate to changes in feeding and fertiliser management. Use of nutritional approaches to reduce N intake and/or reduce soil N load from urine are strategies suggested to reduce N loss at the farm and animal level. For example, feeding high-moisture feeds with lower rumen N degradability such as plantain is expected to reduce urinary N load and nitrate leaching (Bryant et al. 2020). Similarly, feeding low N supplements such as grains can also reduce N intake and improve N use efficiency in the animal.

To further improve gains made in reducing farm N losses, attention has been turned towards animal selection. Animal selection for production and production efficiency traits has been extensively explored, and limited information is available on animal selection for lower environmental footprint traits. Recently MUN has been investigated as a pathway for selecting cows with a lower N loss (Beatson et al. 2019). It has long been recognised that MUN is positively related to urinary N excretion (Spek et al. 2013). While MUN itself is a moderately heritable trait (Beatson et al. 2019), scientists have cautioned that selection for low MUN may impact other production characteristics, including milk yield (Correa-Luna et al. 2019), dry matter intake (Ariyarathne et al. 2021), and may not lead to lower UN excretion at the animal level and/or the farm level (Ariyarathne et al. 2021; Handcock et al. 2021 this Journal).

Changes to nutritional management and animal genetics will likely have implications on the composition of milk and total production which may influence product quality and profit. Consequently the purpose of this research was to compare two farm systems which combine mitigation technologies, including stocking rate, plantain and cows divergent in MUN, to determine the impact on milk yield and milk composition at the herd level.

Materials and methods

The grazing study was conducted between October 2018 and May 2019 at the Lincoln University Research Dairy Farm in Canterbury, New Zealand (43°38′S, 172°28′E). The results presented in this research are part of a longitudinal study comparing farm systems which represent different pathways to achieve environmental, social and economic sustainability. Two farming systems are compared, one which adopts a 15% increase in the average regional stocking rate (3.4 cows/ha) and the other with a 15% decrease in stocking rate. To reduce environmental impact, both farms have reduced N fertiliser inputs with the moderately stocked farm (MSR) buying in up to 0.5 t DM/cow/y as crushed grain as a low-N feed alongside perennial ryegrass and white clover (RGWC) pasture. The low stocking rate farm (LSR) has incorporated plantain diverse pastures on 45% of the farm area and aimed to winter cows on farm to reduce costs and maintain profit. Both systems were managed under irrigation. Details of the farms are presented in Table 1.

Fifty-six crossbred Holstein Friesian x Jersey dairy cows (eight primiparous and 28 multiparous) were blocked according to breeding worth, live weight and age prior to

Table 1 Farmlet details for a moderately stocked farm system supplemented with grain (MSR) and low stocked farm including plantain diverse pastures (LSR)

	MSR	LSR
Stocking rate	3.9 cows/ha	2.9 cows/ha
Farm area	10.35 ha	14.03 ha
N fertiliser use	190 kg N/ha/y to all pastures	150 to ryegrass/ clover and 50 kg N/ha/y to diverse pastures
Supplement use during lactation	0.44 t DM/cow as grain and 0.35 t DM/cow as silage	0.09 t DM/cow as silage
Pasture types	2.8 ha diploid perennial ryegrass and white clover 7.55 ha tetraploid perennial ryegrass and white clover	6 ha diploid perennial ryegrass and white clover 1.5 ha tetraploid perennial ryegrass and white clover 6.45 ha Diverse containing plantain, Italian ryegrass, red clover and white clover

Table 2 Herd details (mean±standard deviation) for a moderately stocked farm system supplemented with grain (MSR) and low stocked farm including plantain diverse pastures (LSR) farmlet with cows of high and low milk urea nitrogen (MUN) breeding values (BV).

	Farmlet		MUN group	
	MSR	LSR	High	Low
No. cows	39	39	12	12
Age (years)	4.41 (±1.8)	4.32 (±1.8)	5.2 (±0.93)	5.1 (±1.02)
BW value	98.3 (±29.0)	102 (±26.8)	72.8 (±29.3)	100 (±20.9)
PW Value	131.2 (±89.7)	126 (±84.8)	71 (±89.2)	114 (±99.2)
MUN BV	-	-	1.81 (±0.3)	-0.63 (±0.3)
Live weight (kg)	475 (±50.8)	473 (±54.6)	461 (±64.1)	476 (±63.0)

Where BW is breeding worth and PW is production worth

calving in August 2018, and randomly assigned to one of the two farm systems (Table 2). To evaluate the interaction between animal selection for MUN and farm system, an additional 12 high and 12 low MUN cows were divided into two equal groups and assigned to either the LSR or MSR farm system. Divergence in MUN was determined based on MUN breeding value (mg/dL) estimated from pedigree and the animal's own MUN records from herd-testing, as described by Beatson et al. (2019). The parent average MUN BV would have been a better indicator for the implications of selection for low MUN in the two farm systems, however, these data were not available.

Management

Over the calving period (August and September) cows were allocated to their farmlets once a minimum of 16 cows from each herd had calved. The majority of cows had calved by the beginning of October and measurements commenced once cows had reached peak milk yield at nine weeks from calving. For both farms grazing management decisions were similar which aimed to utilise pasture grown. Farm walks were carried out weekly to estimate pasture mass of each paddock using a rising plate meter. A seven day grazing plan was developed after each farm walk to maintain consistent allocation for each farmlet. Target pre grazing mass was between 2800-3000 kg DM/ha with pastures grazed to a compressed residual of approximately 4 cm. When surplus or deficits occurred, supplement was made (baleage) or fed out as required. Daily stocking density was similar for both farmlets as all paddocks were approximately 0.5 ha. Cows in the MSR system were offered 2.5 to 3.0 kg DM/day as crushed cereal grain using the in-shed feeding system (crude protein ranging between 15 and 18% and metabolisable energy (ME) content of 13-14 MJ/kg DM). Bloat prevention was by bloat oil in troughs at the first sign of bloat, which occurred in the LSR system in April 2019.

Measurements

Cows were milked twice daily from 0600 and 1430 hours and milk volume was measured at each milking through the Delpro system consisting of in-line flow meters. Milk samples from each cow were collected approximately fortnightly at consecutive afternoon and morning milkings resulting in two samplings per month except at the start and end of the study in October and May, when only one milk sampling was carried out. Twenty millilitres of milk were sampled into bronopol-containing tubes and sent to MilkTest NZ within 24 hours for analysis of fat, protein and lactose (%) concentration along with SCC and milk urea (mg/dL) using a mid-infrared (MIR) CombiFoss machine (Foss Electric, Denmark). Cow live weight was recorded twice daily after milking using walk-over weigh scales. Somatic cell count was transformed to somatic cell score (SCS, $\log_2$(SCC/1000).

Samples of herbage were collected fortnightly from paddocks which cows were grazing during milk sampling. Pluck samples were collected from random locations within each paddock and soon after were sorted into botanical components and dried at 60°C in an air force oven. The oven-dried sample was ground to pass through a 1 mm sieve and analysed for nutrient content by NIRS.

Statistical analysis

All analysis was completed using Genstat (16th edition). Summary statistics (means and standard deviations) for cow and pasture variables were collated through time for each cow or each paddock within each farmlet. To compare the effect of MUN group in the different farming systems on milk yield and milk composition, the milk variables were analysed by repeated-measures analysis of variance using farm system (LSR, MSR) and MUN group and their interaction as the fixed terms and cow replicate as the random term for each repeated herd test date (n=13 test dates). The data included only the 24 cows selected for MUN (n=12 max per MUN group). Total accumulated milk yield and milk solid yield was analysed for variance using farm system and MUN group and their interaction as the fixed terms and cow as the random term.

Results

In both MSR and LSR, the proportion of legume in both farm systems were similar, in spite of differences in N fertiliser rate (185 and 130 kg N/ha respectively). In the diverse pastures (45% of the farm) plantain content ranged from less than 10% in November 2018 to a peak of 45% in April 2019 and a seasonal average of 20% of the offered biomass in diverse pastures or 17% for the whole farm. This resulted in nearly 20% lower grass content in LSR compared with MSR (Table 3).

Table 3 Mean (and standard deviation, SD) days in milk, milk yield and milk composition, pasture cover, botanical content and pasture nutritive value for a moderately stocked farm system supplemented with grain (MSR) and a low stocked farm including plantain diverse pastures (LSR)

	MSR		LSR		
	Mean	SD	Mean	SD	% dif
Days in milk (d)	257	21.4	254	26.5	1.2%
Milk yield (L/cow)	4347	800.4	4158	876.3	4.3%
Milksolid yield (kg/cow)	466	83.9	429	70.2	7.9%
Fat (%)[1]	5.51	0.69	5.41	0.70	1.8%
Protein (%)[1]	4.16	0.38	4.16	0.40	0.1%
Fat+protein (%)[1]	9.67	1.04	9.57	1.05	1.0%
Lactose (%)[1]	4.97	0.11	4.99	0.11	-0.4%
Somatic cell score	2.05	0.44	1.98	0.51	3.3%
Urea N (mg/dL)[1]	12.7	1.6	10.4	1.8	18.7%
Fat yield (kg/d)	230	43.1	213	36.0	7.4%
Protein yield (kg/d)	236	44.2	216	37.5	8.5%
APC (kg DM/ha)	2333	126	2464	200	-5.6%
Grass (%)	79.9	0.13	64.8	0.24	18.9%
Legume (%)	8.4	7.2	10.3	10.6	-22.6%
Plantain (%)	2.7	6.4	16.7	20.9	-518.5%
Dry matter (%)	18	3.4	18	5.0	0.0%
Organic matter (%)	90.7	0.9	90.7	1.1	-0.1%
Crude protein (%)	21.9	3.25	20.4	4.17	6.8%
Neutral detergent fibre (%)	43.8	4.01	42.6	5.28	2.7%
DOMD (%)	73.5	3.37	72.9	4.11	0.7%
Metabolisable energy (MJ/kg/DM)	11.8	0.54	11.7	0.66	0.8%

Values are based on 40 cows per farmlet. Where DOMD is the in vitro digestibility of the organic matter in the dry matter and M/D is megajoules of metabolisable energy per kilogram of dry matter; APC is average pasture cover.

[1] Means are average of herd test day between October 2020 and May 2021 and are not adjusted for test day yield.

Across the season the average pasture mass was around 130 kg DM/ha greater in the LSR compared with the MSR system (Table 3). However loss of pasture control in the LSR system over mid-to-late spring (average pasture mass 2862 kg DM/ha vs 2507 kg DM/ha for LSR and MSR respectively) had a negative impact on pasture quality as frequent rain events and baleage contractor availability prevented timely harvesting of paddocks for control of surplus pasture. Carry-over effects of these impacts influenced not just feed quality with lower crude protein and M/D, but milk yield for cows in LSR was lower during the first half of the season compared to MSR.

Although there was only a 4% difference in total milk yield, the cumulative effect of volume and a 1% higher milk solid concentration resulted in 8% more milk solids in the MSR system (Table 3). Cows in both farm systems had similar fat, protein, lactose concentration and SCS. Mean MUN concentration ranged between 9 and 18 mg/dL from cows in MSR and between 5 and 18 mg/dL for cows in LSR, the latter of which was on average 17% lower than that of the MSR system.

Analysis of the subset of cows selected for divergent MUN, showed that cows selected for high MUN tended towards an 11% greater milk yield (P<0.10, Table 4), but lower milk protein % (P = 0.02) and a trend towards lower total solids % (P=0.06) compared with low MUN cows. Consequently, no significant difference in milk solid yield was detected between cows with high and low MUN (Table 4). Expression of MUN phenotype was evident, irrespective of farm system,

Table 4 Effect of selection for high or low milk urea nitrogen (MUN) on milk yield and milk composition

Farmlet	MSR		LSR			P value		
MUN Group	High	Low	High	Low	SEM	MUN	Farmlet	M × F
Days in milk	270	268	273	256	5.8	0.24	0.60	0.37
Milk yield (litres/cow)	4684	4066	4272	3908	174	0.06	0.26	0.61
Fat (%)	5.36	5.77	5.32	5.77	0.192	0.13	0.94	0.94
Protein (%)	4.12	4.44	4.00	4.46	0.109	0.02	0.75	0.68
Fat + protein (%)	9.5	10.2	9.3	10.2	0.288	0.06	0.86	0.83
Lactose (%)	4.94	4.95	4.99	4.98	0.030	0.97	0.33	0.88
Somatic cell score	1.88	2.17	2.10	1.86	0.137	0.91	0.84	0.18
Urea N (mg/dL)	14.2	11.4	12.5	10.3	0.38	<0.001	0.02	0.59
Fat yield (kg/cow)	237	225	217	195	8.0	0.15	0.04	0.65
Protein yield (kg/cow)	253	236	218	207	8.3	0.25	0.01	0.80
Milk solids yield (kg/cow)	489	461	435	402	15.1	0.17	0.02	0.92

Where SEM is the standard error of the mean for the main effect of MUN group with high MUN cows having nearly 20% higher MUN concentrations. No interactions between farm system type and MUN group was detected.

Discussion

In the current study, adopting a farm system with a moderately high stocking rate and supplementing with concentrate, resulted in greater milk and milk solids yield per cow than did a farm with low stocking rate incorporating plantain-diverse pastures. It is unlikely that the combination of species in the plantain-diverse pastures contributed to the lower observed milk yield as recent meta-analysis (McCarthy et al. 2019) and farm systems study (Al-Marashdeh et al. 2021) have shown that diverse pastures with plantain are able to maintain or improve milk production. The difference in milk production is probably the result of pasture management which led to a loss of quality in the LSR system in late spring, and carry-over effects of low pasture utilisation in early summer. Previous research has demonstrated the impact of low pasture utilisation on reduced milk yield for both ryegrass clover (Hoogendorn et al. 1982) and diverse (Cun et al 2018) pastures, highlighting the importance of green leaf allocation to enable high digestible nutrient intake. In earlier farm system research on the same property, lowering the stocking rate resulted in a positive effect on milk yield compared with a high stocking rate, grain-supplemented group (Chapman et al. 2021). While the study of Chapman et al. (2021) also faced challenges with pasture utilisation, the higher stocking rate of 3.5 cows/ha (compared with 2.9 cows in the present study) and increased use of mowing and topping enabled vegetative high quality pastures to be maintained.

With the exception of MUN, which was lower in LSR, there was no consistent effect of farm system on milk composition. Lack of milk composition response is in agreement with results from short-term grazing studies comparing plantain-diverse with conventional grass-clover pastures which have shown little effect on milk protein content, occasionally lower milk fat content, and regular reductions in MUN (Dodd et al. 2019; Bryant et al. 2018; Totty et al. 2013; Nkomboni et al. 2021). Nutritional manipulation to alter milk composition has been studied extensively and it is generally accepted that altering either milk protein or lactose content is difficult (Emery 1978; Sutton 1989). However, fat content along with MUN are more responsive to dietary manipulations (Sutton 1989).

From a nutritional standpoint MUN generally reflects the crude protein content of the diet, as it is positively related with N intake and blood urea (Spek et al. 2013). Although herbage CP was greater in MSR pastures, when the lower-protein grain is accounted for, it is unlikely that there were large differences in dietary crude protein content between the two systems. Rather the lower MUN concentration of individual cows in the LSR system may arise from other factors related to: timing of grazing and supplementation, greater water intake on diverse pastures, site of protein degradation, energy synchrony in the rumen - all of which are likely to play a role in the circulating concentrations of blood urea (Spek et al. 2013).

In spite of the range of dietary conditions which influence MUN, it is a relatively heritable trait (Beatson et al. 2019). Using animals selected for low MUN in the current study resulted in cows which were 7% less productive compared with cows selected for high MUN (Table 2, Figure 2). Beatson et al. (2019) reported positive genetic and phenotypic correlations between MUN and milk yield and negative genetic and phenotypic correlations between MUN and milk protein percentage, in that cows selected either at the phenotypic level or genetic level for lower MUN would be associated with lower milk yield but higher milk protein percentages. In the current study, an 11% reduction in milk yield for low-MUN cows was partially offset by greater protein composition giving a 7% reduction in milk solid yield. Marshall et al. (2020) also reported that cows selected for lower MUN had greater milk protein percentages. Similar to those in the current study, the cows used by Marshall et al. (2020) were selected based on their MUN breeding value that was calculated using ancestry, in addition to the cow's own MUN phenotype records. Both the current study and that of Marshall et al. (2020) were not designed to test the impact of genetic selection for lower MUN cattle due to incorporating the cow's own MUN phenotype in the estimation of MUN breeding values. Hojman et al. (2004), using a large database of cows in TMR systems, showed similar relationships with yield and protein as the present study, but observed that differences between high and low MUN were more pronounced at the start of lactation as differences in milk composition diminished over time. Arguably, had we used a greater number of cows, and/or full-season lactation data, milk yield differences may have been more pronounced. In the Hojman study, those authors also found a strong negative relationship between MUN and SCC which they were unable to explain and which our current research was unable to support. However, a farm system study, even at these limited animal numbers, are useful as pilot studies to indicate whether there might be obvious management interactions with genetic selection. The mode of action of herb-containing pastures on MUN versus selection for MUN did not appear to off-set each other as the low MUN phenotype was significant under both management regimes.

The purpose for selecting cows with lower MUN was based on the assumption that correlation with blood urea would lead to lower urinary urea excretion. However, recent research would suggest that due to the high inter-cow variability in MUN and urinary N excretion, selection for MUN is unlikely to reduce N loss either at the cow level (Handcock et al. 2021) or whole farm level (Ariyarathne et al. 2021). Furthermore, the results from this study highlight the importance of consideration of other important traits such as milk production which may be affected by selection on MUN alone.

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