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Effect of genetic merit for milk urea on milk production and efficiency of crude protein utilization of grazing cows with contrasting supplement inclusion

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Abstract

Milk urea (MU) has been proposed as a predictor of nitrogen excreted through urine into the environment. The objective of this study was to evaluate milk production performance and efficiency of crude protein utilization (ECPU) of cows with low and high MU breeding values (MUBV) in grazing conditions with two levels of dietary supplementation inclusion. From July 2016 to May 2017, 257 cows were milked once daily with low supplementation (LS; 366 kg/cow/lactation) and 210 cows were milked twice daily with high supplementation (HS; 2,091 kg/cow/lactation). Cows within each herd were ranked as low, intermediate, or high for MUBV. The dataset consisted of 2,318 records of milk production collected from monthly herd-tests of both herds; and 853 additional milk samples obtained at early, mid and late lactation to measure MU. The ECPU was calculated as the proportion of protein yield (PY) with respect to crude protein intake (CPI); with CPI derived from feed intake estimates based on energy requirements. Cows with HS had superior milk yield (MY) and milk solids yield (MSY) [MSY= PY + fat yield (FY)] ($P<0.001$). Feed intake was less in LS ($P<0.001$) but CPI was superior compared to HS. The ECPU was better in HS ($P<0.001$) because of higher PY ($P<0.001$) along with lower CPI ($P<0.001$). Levels of MU were superior for LS because of higher CPI. Cows with low-MUBV had significantly lower MU along with less total daily excretion of MU during the lactation ($P<0.001$). Irrespective of supplementary feed level, cows with low-MUBV had less MY ($P<0.001$). Low-MUBV did not result in improved ECPU for either supplementary feed level: under LS, ECPU was inferior in cows of low-MUBV ($P<0.001$), and this was explained by reduced PY ($P<0.001$).

Keywords: milk urea; breeding values; crude protein utilization; supplementation

Introduction

New Zealand dairy systems are predominantly grass based, although the proportion of supplementary feed has increased in recent decades (Wales & Kolver 2017). The positive response in milk production from grazing cows fed supplements (Berry et al. 2006) has resulted in farmers increasing supplement allocation to milking cows. Fresh grazed pastures are high in crude protein (CP) concentration in early and late lactation (early spring and late autumn, respectively), containing mainly rumen-degradable protein at levels that regularly exceed milk production requirements (Kolver & Muller 1998). Efficiency of CP utilization (ECPU), defined as nitrogen (N) output in milk protein as a percentage of CP in the diet of grazing cows, is generally low. Low ECPU results in increases in excreted N, predominantly in urine (Hristov et al. 2005), and this is associated with increases in soil solution and groundwater nitrate-N and contributes to greenhouse gas emissions. Supplements are typically higher in energy content and lower in CP than pasture (Kolver & Muller 1998) and their inclusion can improve the ECPU of a cow by diluting the dietary CP, and increasing milk production.

The excess of ruminal N is rapidly converted to urea to avoid harming from the excess of ammonia. Urea is transported from the plasma and subsequently is transported to other fluids such as saliva in order to be recycled, or to be excreted in urine but it can also be found in milk. Hence, milk urea (MU) has been proposed as a non-invasive tool to assess inefficiencies of N use and as a predictor of N excreted through urine into the environment (Nousiainen et al. 2004; Jonker et al. 1998). Recently, it was suggested that selecting cows of low MU breeding values (MUBV) would reduce the N leaching by 20% over 20 years as more N would be captured in milk true protein (Beatson et al. 2019), but literature is scarce in regards to milk production performance of these low-MUBV cows.

The objective of the current study was to evaluate the milk production performance and ECPU of cows with low- and high-MUBV under grazing conditions with two levels of concentrate supplementation.

Materials and methods

The current study was carried out in the lower North Island of New Zealand from June 2016 to May 2017 on a herd of 210 cows fed higher levels of non-pasture supplementary feeds (HS) milked twice daily and on a herd of 257 cows fed low levels of supplementary feed (LS) milked once daily. Planned start of calving commenced in the second half of July for both herds. Each herd had access to fresh ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture (RGWC) after each milking.

In LS, cows were milked once daily at 6:30 am throughout the season and had daily access to an herb crop [mix of plantain (*Plantago lanceolata*), chicory (*Cichorium intybus*) and red clover (*Trifolium pratense*)] at an allowance of 3.5 kg dry matter (DM) per cow from December to April. In March and May, lucerne (*Medicago sativa*) was grazed at an offered allowance of 3 kg DM per cow per day. Turnip crop (*Brassica campestris* ssp. *rapifera*) was fed at an allowance of 2.6 kg DM per cow in February. Pasture silage was fed directly on paddock in August and from March to May at a rate of 3.5 kg of DM per cow per day.

In HS, cows were miked daily at 5.30 am and 2.30 pm throughout the season and maize silage and grain-based concentrate were fed during the lactation at 3.5 kg DM per cow per day before the afternoon milking and 1 kg DM per cow per day inside the parlour at each milking, respectively. Pasture silage was fed directly on paddock in January at a rate of 3 kg of DM per cow per day. In March, dried distillers grains were fed at a rate of 0.75 kg DM per cow during the morning milking and turnip crop was grazed in strips at an allowance of 2 kg DM per cow per day.

Herbage mass measurements of RGWC were taken before and after each grazing event with a rising-plate meter following a 'W' pattern across the grazing area. Three quadrat cuts (0.1 m^2) were taken both before and after grazing to quantify pre- and post-grazing herbage mass (kg DM per ha) of the grazed crops. These measurements enabled calculation of apparent pasture and crop utilization, and also the proportion of herbage allocated to cows before each herd test.

Samples (approximately 1,500 g of wet weight) of fresh pastures and crops were taken by hand-plucking, and these, along with samples of silage and concentrate, were freeze-dried and ground (Wiley mill) to pass through a 1.0 mm screen. All samples were analysed by the near infrared reflectance spectroscopy technique (Corson et al. 1999) to evaluate metabolizable energy (ME) and CP.

Daily live weight (LW) measurements were available and body condition scores (BCS) estimated at each herd test by a single research technician using a 10-point scale (Macdonald & Macmillan 1993). Yields of milk (MY), fat (FY) and protein (PY) and somatic cell count were collected from monthly herd test records. Lactation curves for milk production traits and cow performance were obtained using Legendre polynomials of third order generating daily records for each cow during the season (Silvestre et al. 2006). Live weight loss (LW_{loss}) and BCS loss (BCS_{loss}) were calculated as the sum of LW (or BCS) loss between day of reference with respect to a previous day in the first 100 days of lactation.

Additionally, milk samples from each cow were taken in early (September), mid (December) and late (March) lactation using herd-test milk meters provided by Livestock Improvement Corporation. These samples were analysed by MilkTestNZ (Hamilton, NZ) using the CombiFoss technique (Arunvipas et al. 2003) for MU (mg/dL) content and lactose percentage. Each MU record was converted into MU yield (MUY) (g MU/cow/day) using daily MY.

Total net energy requirements for maintenance, pregnancy, production and daily LW variation were calculated using the equations provided by Berry et al. (2006). Apparent DM intake (DMI) (kg DM/cow/day) was estimated by dividing the daily ME expenditure by the ME content of any feed offered on the day of the herd test after multiplying total net energy requirements by 11.85 MJ ME. Concentration of CP (%) in feed was used to calculate CP intake (CPI). Daily ECPU was calculated by dividing PY by CPI.

Each cow's MUBV was estimated from the dataset of this study using a single-trait repeatability animal model as described by López-Villalobos et al. (2018). The PROC RANK procedure of SAS was utilised to obtain three MUBV categories within cows of the same age and breed in each herd: low, intermediate and high. Only cows of high- and low-MUBV were considered in this study. Least-squares means of the variables were obtained using the PROC MIXED procedure of SAS with a mixed model that included the fixed effects of herd, lactation number, MUBV category and as co-variables deviation from median calving date, proportion of Holstein-Friesian (F) and heterosis effect between F and Jersey (J), and the random effect of cow.

Results

Table 1 presents milk production least-squares means of cows with low and high MUBV with low and high supplementation after adjustment for lactation number, deviation from median calving date, proportion of F and F×J heterosis effects. An increase in MY for high-MUBV cows was observed, irrespective of supplementation (Figure 1a). The difference in MY between high versus low-MUBV was 11% and 7% for LS and HS, respectively ($P<0.001$). With respect to milksolids yield (MSY) the same trend was observed as in the case of MY but the differences remained at a significant level only in LS (Table 1). Lactation length was the same for low and high MUBV on both LS and HS. While ECPU of low and high MUBV of HS cows was similar, in LS the mean ECPU was one percentage point lower for the low MUBV when compared to high MUBV ($P<0.001$) (Figure 1b).

A higher proportion of pasture allocated to LS cows during the lactation (92% vs 60% of total feed intake) led to a diet higher in CP (19.3% vs 15.1%) that resulted in higher CPI ($P<0.001$) for all LS cows. Values of CP for LS were 18.6, 19.0 and 20.4 in early, mid and late lactation, and 14.5, 14.1 and 16.2 in HS, respectively. Irrespective of MUBV category, cows fed HS had significantly higher DMI. In the LS herd, DMI of low-MUBV cows was 3% less when compared to high MUBV ($P<0.001$) and these differences were reflected in CPI.

Compared to high MUBV, lower MU on low MUBV was observed regardless of dietary supplementation inclusion (Figure 2a). The difference in MU between low- and high-MUBV cows was 9.30 and 6.92 mg/dL in LS and HS along the lactation, respectively. Mean values of MUY were similar for low-MUBV cows in LS and HS herds, and for high MUBV in LS and HS herds and this was attributed to the compensation between MY and MU observed in each treatment within each herd (Figure 2b).

There were no significant differences for LW between treatments (Figure 3a). An interaction between MUBV categories and supplementation (Table 1) with respect to

BCS and its correspondent mobilization in the first 100 days of lactation was observed. In LS, cows of low MUBV had lower LW_{loss} when compared to high-MUBV cows, and in HS cows of low MUBV there was a higher LW_{loss} when compared to high MUBV cows, but significances were only observed between herds. Irrespective of herd, BCS was higher in low MUBV when compared to high MUBV, and this was accompanied by a minor BCS_{loss} in the first 100 days of lactation in each instance (P<0.001) (Figure 3b).

Discussion

The aim of the current study was to compare the effect of low and high MUBV in cows on milk production performance and ECPU under grazing conditions with two supplementation levels. It was confirmed that cows with low MUBV produce milk with low concentrations of MU at both supplementation levels (Figure 2a). Notwithstanding this, at each level of supplementation, cows with low MUBV produced less milk than cows with high-MUBV. Additionally, no improvements in ECPU were observed with either of the two levels of supplementation (Table 1 and Figure 1b). On the contrary, a marginal improvement in ECPU in cows of high MUBV fed LS was observed, but this was explained by higher increases in PY (9%) than the increase observed in the CPI (3%), when compared to cows of low-MUBV fed LS. Literature is scarce in regards to the genetic effect of MUBV on MY, but in line with the current study, Sebek et al. (2007) reported the absence of a relationship between MUBV and ECPU by analysing more than 15,700 records from 723 cows in 26 experiments. In

Table 1 Least-squares means (± standard errors) of production, live weight, intakes and crude protein efficiency in grazing cows of low and high milk urea breeding value (MUBV) with two levels of supplementation.

	Low supplement		High supplement	
	Low MUBV	High MUBV	Low MUBV	High MUBV
N	82	86	68	70
MU breeding value	-0.57	3.24	0.11	3.11
Lactation length, days	274 ± 3	277 ± 3	269 ± 4	273 ± 4
Milk yield, kg	3900 ± 86^{d}	4369 ± 83^{c}	4934 ± 99^{b}	5282 ± 99^{a}
Milksolids yield, kg	368 ± 7^{c}	397 ± 7^{b}	420 ± 8^{a}	431 ± 8^{a}
Fat yield, kg	208 ± 4^{c}	222 ± 4^{b}	231 ± 5^{ab}	236 ± 5^{a}
Protein yield, kg	160 ± 3^{c}	175 ± 3^{b}	188 ± 4^{a}	195 ± 4^{a}
Lactose yield, kg	198 ± 5^{c}	221 ± 5^{b}	280 ± 5^{a}	291 ± 5^{a}
SCS [1]	5.71 ± 0.13^{a}	5.65 ± 0.13^{a}	4.93 ± 0.15^{b}	5.2 ± 0.2^{b}
Live weight, kg	475 ± 6	479 ± 6	479 ± 7	473 ± 7
Liveweight loss [2], kg	13 ± 4^{c}	19 ± 4^{bc}	34 ± 4^{a}	30 ± 4^{ab}
BCS	4.73 ± 0.03^{a}	4.53 ± 0.03^{b}	4.31 ± 0.04^{c}	4.19 ± 0.04^{d}
BCS loss [3]	0.28 ± 0.02^{c}	0.41 ± 0.02^{b}	0.42 ± 0.03^{b}	0.49 ± 0.03^{a}
DMI, kg/day	15.67 ± 0.07^{c}	16.19 ± 0.07^{b}	18.12 ± 0.14^{a}	18.19 ± 0.14^{a}
CPI, kg/day	3.03 ± 0.02^{b}	3.13 ± 0.02^{a}	2.69 ± 0.04^{c}	2.71 ± 0.04^{c}
MU, mg/dL	23.78 ± 0.53^{b}	33.08 ± 0.52^{a}	17.5 ± 0.6^{c}	24.44 ± 0.62^{b}
MUY, g	911.4 ± 25.3^{b}	1355.1 ± 24.4^{a}	921.7 ± 29.1^{b}	1332.1 ± 29.1^{a}
ECPU, %	19.28 ± 0.22^{c}	20.27 ± 0.22^{b}	27.2 ± 0.4^{a}	27.26 ± 0.42^{a}

[1] The somatic cell count records were log-transformed to SCS. BCS on a 1-10 scale. [2] Sum of liveweight loss between day of reference with respect to a previous day in the first 100 days of lactation. [3] Sum of BCS loss between day of reference with respect to a previous day in the first 100 days of lactation. [abcd] means with different superscripts within rows indicates that were significantly different (P<0.05).

Figure 1 Predicted lactation curves of (a) milk production (kg milk/cow) and (b) efficiency of crude protein utilization (ECPU) (%) of grazing cows of low and high breeding value for milk urea (MUBV) with low (LS) and high (HS) supplementation. Legend: LS_Low MUBV (.......); LS_High MUBV (——); HS_Low MUBV (●●●●●); HS_High MUBV (▬).

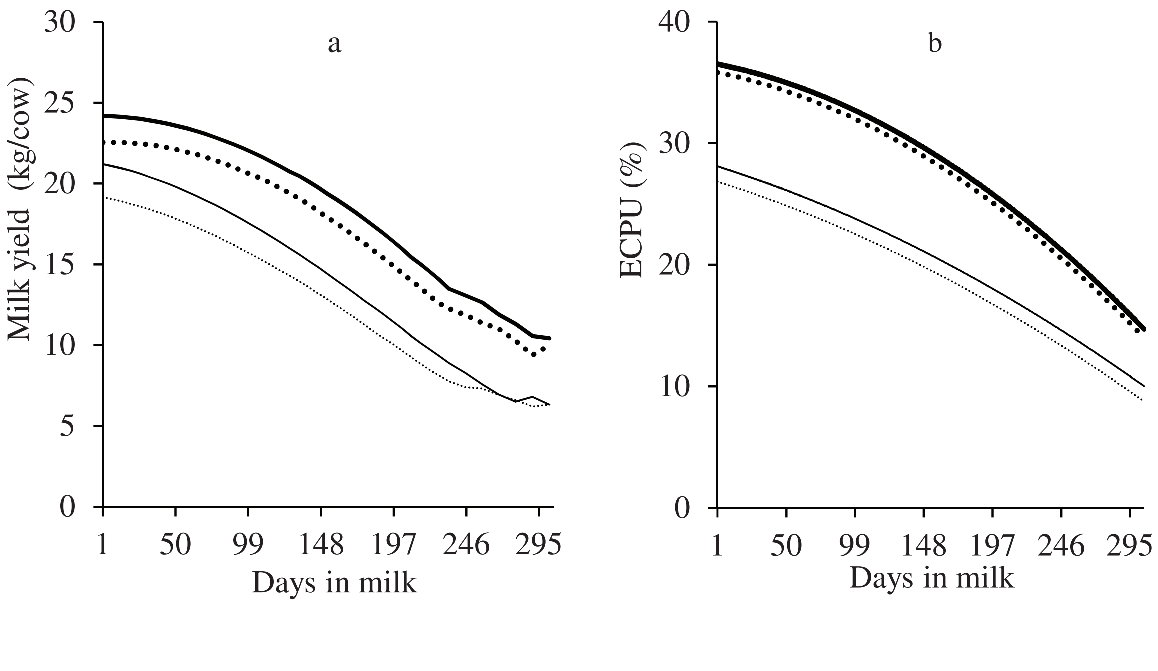


Figure 2 Predicted lactation curves of (a) milk urea (mg/dL) and (b) milk urea yield (g) of grazing cows of low and high breeding value for milk urea (MUBV) with low (LS) and high (HS) supplementation. Legend: LS_Low MUBV (.......); LS_High MUBV (——); HS_Low MUBV (●●●●●); HS_High MUBV (▬).

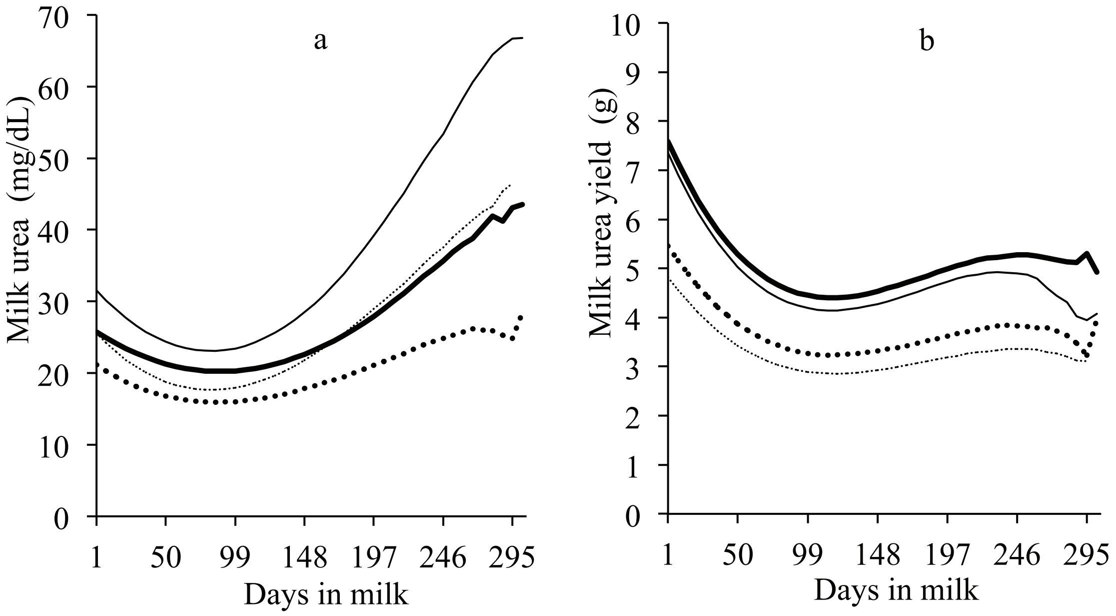
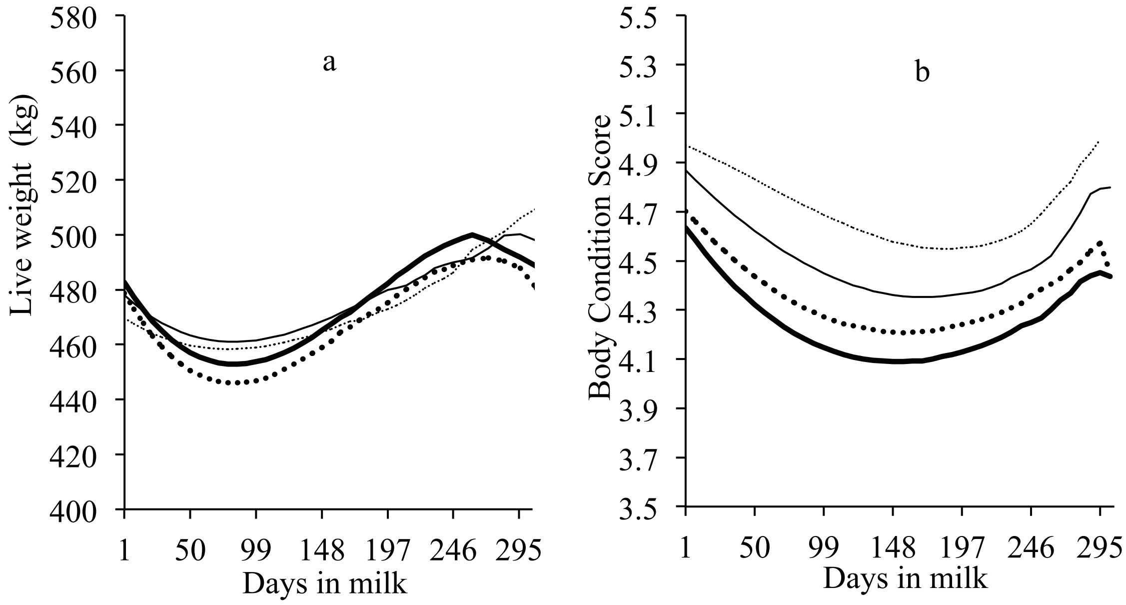


Figure 3 Predicted lactation curves of (a) live weight (kg) and (b) body condition score of grazing cows of low and high breeding value for milk urea (MUBV) with low (LS) and high (HS) supplementation. Legend: LS_Low MUBV (.......); LS_High MUBV (——); HS_Low MUBV (●●●●●); HS_High MUBV (▬).



a study by Wood et al. (2003) the heritability for MU ranged from 0.44 to 0.59, indicating that MU can be included in a genetic selection plan, but there is a lack of estimates for genetic correlations of MU with production and fertility traits in grazing cows. Selection for low-MUBV might result in unfavourable effects on other traits, such as the reduction in MY observed in both HS and LS herds in the current study. Berry et al. (2006) corroborated a moderate heritability of energy balance and energy partition towards milk production by selecting high genetic merit cows. In the current study, energy balance was not calculated, but it can be reflected indirectly in LW_{loss} and BCS_{loss}. In both LS and HS herds, a lower BCS_{loss} for low-MUBV cows in the first 100 days of lactation resulted in lower MY when compared to high-MUBV cows. In regards to LW_{loss}, only under LS did a lower LW_{loss} for low-MUBV cows accompanied by a lower MY, compared to high-MUBV cows. Cows fed HS had no differences in LW_{loss} irrespective of MUBV, but MY was higher for the high-MUBV cows. There might be an interaction between energy balance of cows with different milking frequency (McNamara et al. 2008) and energy content of the different diets offered to both LS and HS herds (Kolver & Muller 1998).

In agreement with the current study, a significant reduction in milk production was reported when comparing cows milked once *vs* twice daily (Figure 1a) (Clark et al. 2006). By increasing the milking interval in cows fed LS, a suppression of nutrients partitioned towards the mammary gland would lead to a reduction in milk production (McNamara et al. 2008), compared to cows fed HS. The difference in MY between low-MUBV cows fed LS, compared to HS, was 1034 kg of milk and a similar value was observed with high-MUBV cows fed LS compared to HS. Additionally, cows milked once daily and fed LS had a lower DMI, and this was anticipated in line with previous experiments (Holmes et al. 1992).

Irrespective, from the lower DMI of cows fed LS, CPI was increased due to a larger proportion of dietary pasture allocation with higher degradable N and this, along with a reduced PY, resulted in a lower ECPU for cows fed LS compared to HS. A negative, strong relationship between dietary CP and N use efficiency has been previously reported (Hristov et al. 2005). Diets comprised mainly of ryegrass pasture of good quality are moderate in ME and high in CP, and the lower inclusion of concentrate on such diets would reduce the total ME intake. This represents an imbalance of energy:protein ratio in the rumen, interfering with the uptake of CP towards microbial protein synthesis (Kolver & Muller 1998). Additionally, the HS diet provided more energy and less CP, lowering the CPI while increasing the DMI, which resulted in higher PY, and this exacerbated the difference in ECPU between the LS and HS herds.

Milk urea was effectively diminished by reducing CP in the diet (Figure 2a). Ureagenesis occurs in the liver and is a vital mechanism to overcome poisoning from the excess of ammonia present in the systemic circulation. This labile N pool is highly influenced, amongst other factors, by feeding management (Nousiainen et al. 2004). In turn, urea is transported from the plasma to other fluids such as saliva in order to be recycled, and urine to be excreted, but due to its molecular weight and neutral charge urea easily diffuses across cellular membranes where is incorporated to milk. As such, the relationship between urine urea and MU was previously recognized by Jonker et al. (1998). A problem is that these associations are from housed conditions with diets controlled (and reduced) in CP. While finding no improvements in the ECPU by reducing MU in the current study, and by observing inconsistencies in MUY across treatments, it is imperative to verify the implications of different MUBV with respect to blood urea nitrogen and to the total release of N in excreta in pasture-fed cows.

Conclusions

Irrespective of dietary supplementation allocated to each herd, cows of low-MUBV had lower MY. Additionally, MSY resulted lower in low-MUBV treatments, but this was only significant in the LS.

Regardless of dietary CP, reductions of MU during the lactation were not associated with improvements in the ECPU. On the contrary, cows that had higher ECPU also had higher mean MU during the lactation.

Work is still needed to verify whether the reduction of MU of pastured dairy cows would result in less N excreted to the soil.

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