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GENETIC CORRELATION BETWEEN MILK UREA AND EFFICIENCY OF CRUDE PROTEIN UTILIZATION ESTIMATED FROM A RANDOM REGRESSION MODEL

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SUMMARY

The concentration of urea in milk (MU) can be predicted from mid infrared spectra in routine herd testing of dairy cattle. A high positive phenotypic correlation between MU nitrogen and urinary nitrogen has been estimated in controlled indoor trials suggesting selection for low MU nitrogen might reduce urinary nitrogen excretion. Estimates of genetic correlations (r_G) of MU and other traits are required to evaluate the effects of selection for low MU. The aim of the current study was to estimate r_G between MU and efficiency of crude protein utilization (ECPU; ratio between crude protein yield in milk and crude protein intake) throughout the lactation using a random regression animal model (RRM). Results show that r_G between MU and ECPU was positive in early and late lactation but was mostly negative from day 40 to 180 of the lactation (mean=-0.09). The r_G of MU with crude protein (mean=-0.15) and fat (mean=-0.27) percentages were negative. Further research is required to confirm if MU can be used in selection to reduce urea nitrogen excretion and increase ECPU without reducing cow productivity and farm profitability.

INTRODUCTION

New Zealand cows graze almost exclusively on pasture all year round. Consequently, cows consume feed with more protein relative to energy than they require. The efficient conversion of feed protein to milk protein is sensitive to the ratio of protein to energy in the diet. Protein being eaten by the cows is degraded to amino acids and ammonia by rumen microbes. If the diet has an excess of protein and is deficient in energy, rumen microbes are less efficient in capturing available ammonia, therefore the surplus enters the bloodstream and is converted to urea in the liver. The majority of the urea produced in the liver is excreted as urine, however a proportion of urea is diffused to milk (milk urea, MU) through the bloodstream (Roseler *et al.* 1993). New Zealand cows fed at pasture produce greater levels of MU than levels produced by cows fed balanced mixed rations (Garcia-Muniz *et al.* 2013). Urea enters the environment as urine breaks down to ammonia and nitrous oxide at the site of the urine patch making it a major source of air and water pollution in New Zealand. Averaged across the year, 20% of the nitrogen (N) load is leached through the soil (Selbie *et al.* 2015).

Reducing N pollution is an urgent national need and one option may be genetic selection for less urea in urine (UU) thereby reducing the amount of urea reaching the environment. Measuring UU is not feasible in outdoor farming systems and even if practical it is very expensive to measure. However, MU could be useful as an indicator of UU if the strong positive correlation between MU nitrogen and UU nitrogen in controlled indoor experiments (Jonker *et al.* 1998) is confirmed in pastoral circumstances. Milk urea can be determined from mid infrared spectra generated from milk samples used for routine herd testing, but it is not reported to dairy farmers.

Milk urea has also been proposed as an indicator of efficiency of crude protein utilization (ECPU) (Baker *et al.* 1995), which can be defined as the proportion of crude protein produced in milk in relation to the intake of crude protein. Cows with high ECPU likely divert more absorbed protein for milk production rather than excreting and therefore wasting it as urea in urine.

Some authors have reported negative r_G between the concentration of MU and milk production traits (Miglior *et al.* 2007). However, few studies have reported estimates of r_G between MU and protein utilization efficiency traits, other than the negative but non-significant correlations found by Vallimont *et al*. (2011) between MU nitrogen and three feed efficiency traits.

There is evidence to suggest that, the additive genetic variance of longitudinal traits can change over time. Therefore, it is sensible to expect variability in r_G between traits over the different stages of lactation. Random regression models based on test-day records can capture variability in additive genetic and permanent environmental effects over stages of lactation. To our knowledge there is no literature on the variability of r_G between MU and ECPU traits at different stages of the lactation profile. The objective of this study was to estimate r_G between MU and each of ECPU, yields of milk (MY), fat (FY) and crude protein (CPY), percentages of fat (FP) and crude protein (CPP) for every day of lactation in grazing dairy cows in New Zealand using a test-day RRM.

MATERIALS AND METHODS

Data originated from 468 cows on two mixed-breed herds from Massey University in Palmerston North, New Zealand for the 2016 and 2017 production seasons were included in this study. Details of animal management and feeding can be found in Correa-Luna *et al.* (2018).

Daily MY, FY, CPY, FP and CPP were derived from monthly herd-test records. Three additional milk samples from each cow were collected in each production season representing early, mid and late lactation for determination of MU content. Daily ECPU was defined as the ratio of CPY to daily dietary intake of crude protein and expressed as a percentage. For both herds, daily live weight measurements were obtained from an automatic walk over scale in the exit race of the milking shed and body condition scores measurements on a 10-point scale were assigned in synchrony with each herd-test by a single research technician.

Apparent dry matter intake (kg DM consumed/cow/day) was obtained based on summing up the estimated metabolisable energy (ME) requirements for maintenance, pregnancy, production and daily weight variation and then dividing by ME content of the feed offered. Content of crude protein from feed quality analyses were used to calculate crude protein intake (CPI). Cows with a minimum of 3 herd test records and lactation lengths of not less than 150 days and up to 240 days in milk (DIM) were included in the analysis. After editing the data 380 cows remained in the data set.

Co(variance) components corresponding to additive genetic effect for MU, ECPU, MY, FY, CPY, FP and CPP was estimated using bivariate random regression test-day animal models. The model included the fixed effects of herd-test-date and parity, and as covariates, deviation from median calving date, proportion of Holstein-Friesian breed and coefficient of heterosis of Holstein-Friesian and Jersey breeds, and days in milk modelled as second-order orthogonal polynomial. Random effects included in the model were the animal additive genetic, cow-lactation permanent environment, cow permanent environment and residual effects. Animal additive genetic effect was modelled using second-order orthogonal polynomials for all the traits except for MY where a third order polynomial was used. Constant cow permanent environment, cow-lactation permanent environment variances and residual variances were also fitted in the model. Variance and covariance components were estimated using the ASReml package (Gilmour *et al*. 2009). The matrix of additive genetic (co)variances (**C**) for each day of lactation was estimated using the following covariance function, $\mathbf{C} = \mathbf{\Phi} \otimes \mathbf{G} \otimes \mathbf{\Phi}'$ where **G** is the matrix of variances of the random regression coefficients for additive genetic effects between two traits and **Φ** is the matrix of orthogonal polynomial coefficients.

RESULTS AND DISCUSSION

The r_G between MU and ECPU, MY, FY, CPY, FP and CPP fluctuated over the lactation from 1 to 240 DIM (Figure 1). The overall genetic correlation between MU and ECPU was negative (-0.09) but point estimates at specific stages of lactation fluctuated from -0.46 to 0.81 (Table 1). Although the r_G was positive at the beginning, it turned moderately negative by mid-lactation (-0.46). The high positive correlation at the end of the lactation could be an artefact of the mathematical properties of polynomial random regression and reflect the lesser number of herd-test records towards the end of lactations. However, the strong negative r_G between MU and ECPU at the middle of the lactation when cows are producing more milk suggests that efficient cows convert more feed protein into milk protein and produce milk with low content of urea. These cows may divert absorbed proteins in a different manner compared to inefficient cows.

Table 1. Estimates of genetic correlation (r_G) between milk urea (MU) and efficiency of crude protein utilization (ECPU), yield of milk (MY), fat (FY), crude protein (CPY), and percentage of fat (FP) and crude protein (CPP) at different days in milk (DIM) in grazing dairy cows in New Zealand

DIM	$r_{G(MU-ECPU)}$	$r_{G\ (MU-MY)}$	$r_{G\ (MU-FY)}$	$r_{G\ (MU-CPY)}$	$r_{G\ (MU-FP)}$	$r_{G\ (MU-CPP)}$
1	0.25	0.29	0.06	0.27	-0.36	-0.15
60	-0.23	0.16	-0.16	-0.04	-0.23	-0.13
120	-0.46	0.18	-0.14	0.02	-0.29	-0.17
180	-0.11	0.21	0.17	0.16	-0.27	-0.18
240	0.81	0.29	0.55	0.64	-0.28	-0.09

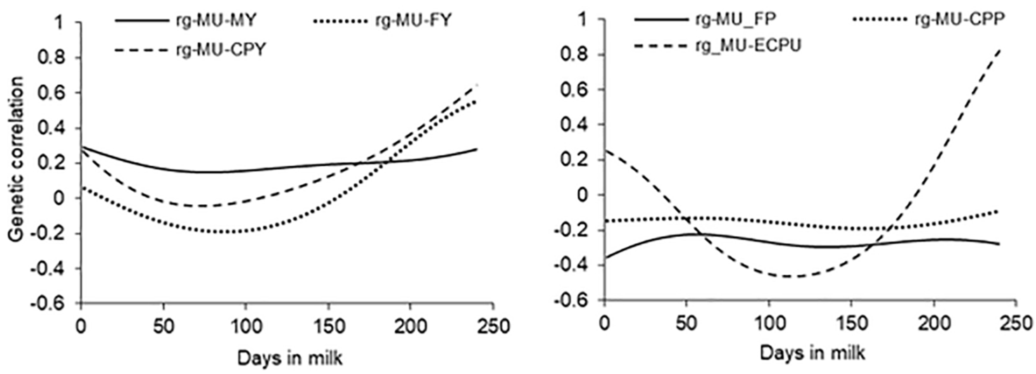

Figure 1. Daily genetic correlations (r_G) between milk urea (MU) and yield of milk (MY), fat (FY), crude protein (CPY), percentage of fat (FP), crude protein (CPP) and efficiency of crude protein and utilization (ECPU) at different days in milk in grazing dairy cows in New Zealand

The estimates of r_G of MU and FP and CPP were negative with some small fluctuations throughout the lactation. The r_G between MU and FP fluctuated from -0.23 to -0.36 and MU and CPP from -0.09 to -0.18 (Table 1). These negative correlations indicate that cows produce milk with high CPP and

FP and low content of MU. Together with the r_G between MU and ECPU these results suggest that cows that allocate more CP from the diet into milk protein divert less urea in milk. However, the r_G between MY and MU was positive throughout the lactation (0.19) with small fluctuations (0.16 to 0.29) (Table 1). A positive relationship between MU and MY has been previously reported by Godden *et al*. (2001) and this might be explained by the increased level of feeding that involuntarily increases the level of protein intake and this also increases the production of milk. Diets with a high CP:energy ratio reduce the efficiency of rumen microbes, with more ammonia converted into urea instead of proteins in milk (Baker *et al.* 1995).

The estimates of r_G of MU with FY and CPY ranged from -0.16 to 0.55 and -0.04 to 0.64 respectively (Table 1). Despite the small sample size used in this study, the average r_G of MU with FY and CPY estimated in this study were within the range reported by Beatson *et al.* (2019) using a much larger data set comprising several mixed-breed dairy herds in New Zealand. Studies by Wood *et al.* (2003) reported r_G of MU and FY and CPY not different from zero.

CONCLUSIONS

The genetic correlation between MU and ECPU was positive in early and late lactation but was mostly negative from day 40 to 180 of the lactation indicating that inclusion of MU in a selection index can cause correlated responses in ECPU. Further research is required to estimate the genetic correlation between MU and urine urea to fully evaluate if MU can be used as a trait to reduce nitrogen excretion in grazing dairy cows.

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