Estimates of genetic parameters for environmental efficiency traits for first lactation Holsteins

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Abstract

Rumination time was assessed as an indicator of efficiency and sustainability in dairy cattle. This study comprised 7782 records on 656 mid-first lactation Holstein cows. Animal models were used for rumination time and methane emission traits, while repeatability animal models were used for feed efficiency and production traits in bivariate analyses to estimate genetic parameters, including heritability, and genetic and phenotypic correlations between all traits. Rumination time had a moderate heritability (0.48±0.14) and genetic correlations of -0.45 (±0.25) with methane production, -0.88 (±0.24) with methane intensity, -0.08 (±0.19) with feed efficiency, and 0.48 (±0.18) with energy corrected milk. Although these findings should be validated in larger datasets, they suggest that rumination time has the potential to be used as an indicator trait for methane emissions and production levels.

Keywords: Rumination time, methane, dairy.

Introduction

Livestock is responsible for 6% of the global anthropogenic greenhouse gas (GHG) emissions (Gerber *et al*., 2013) with methane (CH_4) from the eructation of ruminants being a major contributor (Beauchemin *et al*., 2020). The production of CH_4 also corresponds to a 10% loss of dietary energy (de Haas *et al*., 2011). A decrease in CH_4 emissions would improve both efficiency and sustainability in the dairy sector. The recording of CH_4 and feed efficiency (FE) is costly and time-consuming, making the use of related traits that are inexpensive and easily measured necessary. One candidate indicator trait for CH_4 emissions and FE is rumination time (RT). Measured by automated sensors such as rumination collars, RT is already used at the commercial level in the monitoring of functional and production traits (Kaufman *et al*., 2018). For RT to be an indicator trait, it should be heritable and genetically correlated to traits of interest (Byskov *et al*., 2017). This study aimed to evaluate RT as an indicator of sustainability and efficiency in dairy cows by estimating genetic parameters, phenotypic and genetic correlations among RT, CH_4 emission, FE, and production traits in Canadian Holstein cows.

Material and methods

This study comprised 656 first lactation Holstein cows between 110 and 210 days in milk. Measured traits were rumination time (RT), methane production (CH_4), methane yield (MeY), methane intensity (MeI), dry matter intake (DMI), feed efficiency (FE), metabolic body weight (MBW), and energy corrected milk (ECM). Rumination time in minutes per day was obtained from Heatime® neck collars, (SCR HiTag, Allflex, Netanya, Israel) (Schirmann *et al*., 2009; Andreen *et al*., 2021). Milk samples were collected weekly and analysed by Lactanet Canada (Guelph, ON) for fat and protein content in kilograms. Energy corrected milk was calculated, where ECM = (0.25 x milk) + (12.2 x fat) + (7.7 x protein) (Sjaunja *et al*., 1990). Daily live body weight (BW) records were used for the calculation of MBW as $BW^{0.75}$. Records for DMI in kilograms were obtained as the product between total mixed ration (TMR) intake in kilograms and the calculated dry matter percentage in the diet, where TMR intake was calculated daily as the difference between offered and leftover feed. Feed efficiency was calculated by a recursive linear transformation of DMI based on the genetic (co)variances among DMI, ECM and MBW (Jamrozik *et al*., 2021). Methane emission was obtained using the GreenFeed® System (C-Lock Inc., Rapid City, South Dakota, USA) (Hristov *et al*., 2015; Huhtanen *et al*., 2015). Methane records were used to calculate MeY and MeI as grams of methane per kilograms of DMI and ECM, respectively. Each trait was assessed for outliers at three standard deviations from the average. All traits had to have a minimum of two records per week of lactation to be considered for analysis, where the week of lactation was defined using the milk test day. Finally, all traits were averaged for the week of lactation. Cows had repeated records of weekly averages for DMI, FE, ECM and MBW.

Statistical models

Animal models were used for RT, MeY and MeI, while repeatability animal models were used for FE, DMI, ECM, and MBW in bivariate analyses to estimate genetic parameters. All (co)variance components were estimated using the average information residual maximum likelihood algorithm in ASREML 4.0 (Gilmour *et al*., 2015). For each trait, heritability was the average result from all bivariate combinations. In general, the model used in this study was:

$$Y_{ijklm} = \mu + AC_i + WL_j + YS_k + a_l + pe_l + e_{ijklm},$$

where Y_{ijklm} represents the m^{th} phenotype (for RT, CH_4, MeY, MeI, FE, DMI, ECM, and MBW) of the l^{th} animal; μ is the overall mean of the trait; AC_i is the fixed effect of the i^{th} age at calving class in months (nine classes); WL_j is the fixed effect of the j^{th} week of lactation (fifteen levels); YS_k is the fixed effect of the k^{th} year and season of calving class (sixteen classes); a_l is the random additive genetic effect of the l^{th} cow; pe_l is the random permanent environmental effect (for FE, DMI, ECM and MBW) of the l^{th} cow, and e_{ijklm} is the random residual error term.

Results and discussion

Heritabilities

The heritability (h^2) estimates in Table 1 show that selection is possible for all analysed traits. The estimated RT h^2 (0.48$\pm$0.14) was larger than 0.33$\pm$0.16 and 0.34$\pm$0.05 previously reported (Byskov *et al*., 2017; Moretti *et al*., 2018). However, these studies used different trait definitions for RT, which could affect h^2 estimates. Estimated heritabilities of CH_4, MeI, and MeY are found to range from 0.05 to 0.38 (de Haas *et al*., 2011; Manzanilla-Pech *et al*., 2021) and the variation in the results can be attributed

Table 1. Genetic correlation (above diagonal), heritability (diagonal), and phenotypic correlation (below diagonal), for rumination time (RT), methane production (CH_4), methane yield (MeY), methane intensity (MeI), feed efficiency (FE), dry matter intake (DMI), energy corrected milk (ECM), and metabolic body weight (MBW).

	RT	CH_4	MeY	MeI	FE	DMI	ECM	MBW
RT (min/day)	**0.48 (0.14)**	-0.45(0.25)	NA	-0.88 (0.24)	-0.08 (0.19)	0.17 (0.14)	0.48 (0.12)	-0.24 (0.13)
CH_4 (g/day)	-0.10 (0.06)	**0.42 (0.12)**	0.85 (0.50)	0.48 (0.23)	0.13(0.18)	0.81(0.10)	0.76(0.14)	0.67(0.10)
MeY (g/kg)	NA	0.46 (0.04)	**0.12 (0.10)**	0.84 (0.62)	-0.91 (0.24)	-0.92 (0.12)	-0.37 (0.29)	0.04 (0.29)
MeI (g/kg)	-0.26 (0.06)	0.57 (0.04)	0.39 (0.05)	**0.36 (0.13)**	0.04 (0.22)	-0.17 (0.16)	-0.81 (0.08)	0.66 (0.13)
FE	0.05 (0.09)	0.02 (0.09)	-0.60 (0.06)	0.06 (0.09)	**0.13 (0.07)**	0.69 (0.14)	-0.06 (0.29)	-0.08 (0.30)
DMI (kg)	0.17 (0.07)	0.50 (0.05)	-0.70 (0.04)	-0.03 (0.07)	0.84 (0.01)	**0.24 (0.07)**	0.56 (0.17)	0.40 (0.21)
ECM (kg)	0.21 (0.07)	0.37 (0.06)	-0.06 (0.07)	-0.69 (0.04)	-0.07 (0.03)	0.34 (0.03)	**0.32 (0.07)**	-0.01 (0.21)
MBW ($kg^{0.75}$)	-0.17 (0.08)	0.45 (0.07)	0.01 (0.08)	0.43 (0.08)	-0.15 (0.04)	0.22 (0.04)	-0.03 (0.04)	**0.44 (0.11)**

to the environmental impact on the methane produced by cows, and the method of measurement (López-Paredes *et al*., 2020). The h^2 for FE (0.13±0.07) was within the reported range for FE (0.01 to 0.40) (de Haas *et al*., 2011; Vallimont *et al*., 2011). Thus, improvements in FE could be possible through selection, however, correlation with other economically important traits should be assessed.

Genetic correlations

Genetic correlations were estimated between all traits (Table 1). The bivariate analysis between MeY and RT did not converge, and this may have been caused by the model not being robust enough to estimate parameters for all traits in a small data set. Rumination time was uncorrelated to FE and had negative correlations with CH_4 (-0.45±0.25), MeI (-0.88±0.24) and MBW (-0.24±0.12) while showing positive correlations with the remaining traits. The genetic correlations between RT and ECM (0.48±0.12) could be a relationship to be exploited by selection programs. Greater rumination and production could be linked to a greater intake by the cows, as shown by the correlations between RT and DMI (0.17±0.14), and between ECM and DMI (0.55±0.16). Additionally, the increased intake could suggest a faster passage rate, and lower fermentation rate (Ramin and Huhtanen, 2013), possibly explaining the association between RT and $CH_{4,}$ and between RT and MeI.

Conclusion

The goals of this study were to estimate genetic parameters for automatically recorded RT and identify if RT is genetically correlated to efficiency, methane production, yield and intensity, and milk production. Our findings show that RT is heritable and is a candidate trait for the identification of low-emitting and high-producing animals with no direct impact on efficiency.

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