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

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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.

Livestock is responsible for 6% of the global anthropogenic greenhouse gas (GHG) emissions (Gerber et al., 2013) with methane (CH₄) from the eructation of ruminants being a major contributor (Beauchemin et al., 2020). The production of CH₄ also corresponds to a 10% loss of dietary energy (de Haas et al., 2011). A decrease in CH₄ emissions would improve both efficiency and sustainability in the dairy sector. The recording of CH₄ 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 CH₄ 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, CH₄ emission, FE, and production traits in Canadian Holstein cows.

Introduction

Abstract
This study comprised 656 first lactation Holstein cows between 110 and 210 days in milk. Measured traits were rumination time (RT), methane production (CH₄), methane yield (MeY), methane intensity (Mel), 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 $ECM = (0.25 \times milk) + (12.2 \times fat) + (7.7 \times protein)$ (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 Mel 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.

Animal models were used for RT, MeY and Mel, 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, CH₄, MeY, Mel, FE, DMI, ECM, and MBW) of the $l^{th}$ animal; $\mu$ 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.

The heritability ($h^2$) estimates in Table 1 show that selection is possible for all analysed traits. The estimated RT $h^2$ (0.48±0.14) was larger than 0.33±0.16 and 0.34±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 CH₄, Mel, 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 to differences in the study designs and data collection methods.
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).

<table>
<thead>
<tr>
<th></th>
<th>RT (min/day)</th>
<th>CH$_4$ (g/day)</th>
<th>MeY (g/kg)</th>
<th>MeI (g/kg)</th>
<th>FE</th>
<th>DMI (kg)</th>
<th>ECM (kg)</th>
<th>MBW (kg$^{0.75}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT</td>
<td>0.48 (0.14)</td>
<td>-0.45 (0.25)</td>
<td>NA</td>
<td>-0.88 (0.24)</td>
<td>-0.08 (0.19)</td>
<td>0.17 (0.14)</td>
<td>0.48 (0.12)</td>
<td>-0.24 (0.13)</td>
</tr>
<tr>
<td>CH$_4$</td>
<td>-0.10 (0.06)</td>
<td>0.42 (0.12)</td>
<td>0.85 (0.50)</td>
<td>0.48 (0.23)</td>
<td>0.13 (0.18)</td>
<td>0.81 (0.10)</td>
<td>0.76 (0.14)</td>
<td>0.67 (0.10)</td>
</tr>
<tr>
<td>MeY</td>
<td>NA</td>
<td>0.46 (0.04)</td>
<td>0.12 (0.10)</td>
<td>0.84 (0.62)</td>
<td>-0.91 (0.24)</td>
<td>-0.92 (0.12)</td>
<td>-0.37 (0.29)</td>
<td>0.04 (0.29)</td>
</tr>
<tr>
<td>MeI</td>
<td>-0.26 (0.06)</td>
<td>0.57 (0.04)</td>
<td>0.39 (0.05)</td>
<td>0.36 (0.13)</td>
<td>0.04 (0.22)</td>
<td>-0.17 (0.16)</td>
<td>-0.81 (0.08)</td>
<td>0.66 (0.13)</td>
</tr>
<tr>
<td>FE</td>
<td>0.05 (0.09)</td>
<td>0.02 (0.09)</td>
<td>-0.60 (0.06)</td>
<td>0.06 (0.09)</td>
<td>0.13 (0.07)</td>
<td>0.69 (0.14)</td>
<td>-0.06 (0.29)</td>
<td>-0.08 (0.30)</td>
</tr>
<tr>
<td>DMI</td>
<td>0.17 (0.07)</td>
<td>0.50 (0.05)</td>
<td>-0.70 (0.04)</td>
<td>-0.03 (0.07)</td>
<td>0.84 (0.01)</td>
<td>0.24 (0.07)</td>
<td>0.56 (0.17)</td>
<td>0.40 (0.21)</td>
</tr>
<tr>
<td>ECM</td>
<td>0.21 (0.07)</td>
<td>0.37 (0.06)</td>
<td>-0.06 (0.07)</td>
<td>-0.69 (0.04)</td>
<td>-0.07 (0.03)</td>
<td>0.34 (0.03)</td>
<td>0.32 (0.07)</td>
<td>-0.01 (0.21)</td>
</tr>
<tr>
<td>MBW</td>
<td>-0.17 (0.08)</td>
<td>0.45 (0.07)</td>
<td>0.01 (0.08)</td>
<td>0.43 (0.08)</td>
<td>-0.15 (0.04)</td>
<td>0.22 (0.04)</td>
<td>-0.03 (0.04)</td>
<td>0.44 (0.11)</td>
</tr>
</tbody>
</table>
to the environmental impact on the methane produced by cows, and the method of measurement (López-Paredes et al., 2020). The h² 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. Ruminating time was uncorrelated to FE and had negative correlations with CH₄ (-0.45±0.25), Mel (-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 CH₄ and between RT and Mel.

**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.

**Acknowledgement**

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**References**


