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Potential for genetic selection of feed efficiency traits in Holstein dairy calves

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Introduction

Feed efficiency is integral for improving profitability and sustainability in dairy cattle production. Genetic selection for calf feed efficiency has the potential to produce calves that meet target growth rates without increasing feed inputs, thereby reducing rearing costs. Calf feed efficiency may also facilitate early prediction of cow feed efficiency, provided a favourable genetic correlation exists. Previous studies have investigated the genetic correlation of feed efficiency at different life stages (Khanal *et al*., 2024; Hermisdorff *et al.,* 2026). The objective of this study was to estimate genetic parameters for calf feed efficiency traits and explore the genetic correlation between calf and first-parity cow feed efficiency.

Materials & Methods

This study used data from the Efficient Dairy Genome Project (EDGP), the Resilient Dairy Genome Project (RDGP) and the Net-Zero Dairy Genome Project (NDGP). Data were collected from the Ontario Dairy Research Centre (Elora, ON, Canada) from July 2016 to April 2024. The data consisted of 938 Holstein calves with a total of 4,662 weekly records for calf feed efficiency traits, and 7,910 weekly residual feed intake (RFI) records from 474 of the same animals that had records at both life stages (i.e. calf and first parity cow).

Calf Data Collection. Starting at day five of life, calves were housed in group pens with access to automatic feeders for *ad lib* milk replacer (fed at 150 g/L, maximum of 12L/day at start of weaning, step-down reduction weaning from day 28 to 57 of life) and 22% calf starter (dispensed in 30-gram increments, maximum 6kg/day per calf). The milk replacer and calf starter contained 4.55 Mcal of metabolizable energy (ME) per kilogram of powder and 2.51 Mcal/kg of ME on a dry matter basis, respectively. The dry matter and ME components of the milk replacer and starter were used to calculate the total metabolizable energy intake (MEI) from both diets. The MEI phenotype was weekly averages of MEI over the pre-weaning (PreW; day 5 to 28 of life) and peri-weaning (PeriW; day 46-60 of life) periods. Data from weeks four to six of life, covering the weaning transition, was not included. Weekly averages of calf weights were interpolated from three manual measurements (birth, day 30, and day 60 of life)to calculate weekly metabolic body weight (MBW) as (average body weight)$^{0.75}$ and weekly average daily gain (ADG) within the PreW and PeriW periods. Weekly ADG was calculated as the difference between weekly weights divided by the seven-day period. Calf feed efficiency was defined as a residual of MEI (RMEI) genetically independent of ADG and MBW and was derived using a recursive model approach (Jamrozik *et al*., 2021).

Cow Data Collection. Weekly Phenotypic RFI in first parity cows from weeks 9 to 44 of lactation was estimated using the following model:

$$DMI_{ij} = \beta_1 ECM_i + \beta_2 MBW_i + YS_j + e_{ij}, \quad (1)$$

where DMI_{ij} is weekly dry matter intake of cow i born in the year-season j, ECM_i is energy corrected milk values of cow i, MBW_i is metabolic body weight of cow i, β_1 and β_2 are coefficients of the linear regression on ECM and MBW, respectively, YS_j is the effect of the year-season of birth j, and e_{ij} is the residual effect, i.e. the RFI of cow i. Cow management and details of the RFI estimation are given in Hermisdorff *et al*. (2026).

Variance Component Estimation. A four-trait repeatability model including ADG, MBW, MEI, and RFI was fitted separately for the PreW and PeriW period using ASREML 4.2 (Gilmour *et al.*, 2015). The models were defined as:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{Wp} + \mathbf{e}, \quad (2)$$

where **y** represents the vector of observations for each trait, **X** is the incidence matrix for fixed effects in vector **b**, **Z** is the incidence matrix for animal additive genetic effects in the vector **a**, **W** is the incidence matrix for permanent environmental effects in the **p**, and **e** is a vector of residual effects. Fixed effects in the models for all traits for both the PreW and PeriW period included the age of the calf (in weeks), year-season of birth, weekly scour incidence, trial participation (five levels: 0, not involved in trial; 1-4, corresponding to four possible diet treatments) for all calf traits, dam parity for calf MBW, and week of lactation for cow RFI.

Breeding Value Correlations. Relative breeding values (breeding values standardized with an average of 100 and SD of 5, with higher values indicating favourable outcome for trait) for cow traits potentially genetically correlated with calf RMEI were provided by Lactanet (Guelph, ON). Correlations were estimated following Alvarenga *et al*. (2022), where breeding value observations are weighed based on their reliabilities, then adjusted following Calo *et al*. (1973), where each weighted correlation is multiplied by:

$$r_{gF,T} = \frac{\sqrt{\sum_{i=1}^{n} RL_{F_i} \times \sum_{i=1}^{n} RL_{T_i}}}{\sqrt{\sum_{i=1}^{n} (RL_{F_i} \times RL_{Ti})}} \times r_{F,T}, \quad (3)$$

where $r_{gF,T}$ represents the approximate genetic correlation between PreW-RMEI or PeriW-RMEI and each evaluated cow trait, RL_{Fi} represents the individual sire reliabilities for PreW-RMEI or PeriW-RMEI, RL_{Ti} represents the individual sire reliabilities for each evaluated cow trait, n represents the number of sires of phenotyped daughters, and $r_{F,T}$ represents the weighted correlation coefficient. The standard errors of the correlations were calculated using the following formula:

$$SE_{gF,T} = \sqrt{\frac{1 - r_{gF,T}^2}{n-2}}. \quad (4)$$

Significant correlations were identified using a two-tailed t-test with a significance threshold of α=0.05, and 55 degrees of freedom where the t-statistic was compared to a critical value of 2.004 and calculated as:

$$t_{gF,T} = \frac{|r_{gF,T}|}{SE_{gF,T}}. \quad (5)$$

Results & Discussion

Summary statistics for calf and cow phenotypes are presented in Table 1.

Genetic parameters for PreW and PeriW feed efficiency traits are presented in Tables 2 and 3, respectively. Heritability estimates for calf feed intake and energy sink traits were consistent with previous estimates in Holstein heifers (Khanal *et al.,* 2024). Estimates for PreW-RMEI and PeriW-RMEI were lower than those reported in growing animals (Berry and Crowley, 2013). Due to recursive modelling, RMEI in both time periods was genetically independent from calf energy sinks (Jamrozik *et al.,* 2021). Contrasting genetic relationships between cow

Table 1. Mean and standard deviation (within brackets) for pre-weaning calf (PreW), peri-weaning calf (PeriW), and first parity cow feed efficiency phenotypes.

	No. of records	No. of animals	Mean (SD) PreW[1]	PeriW[2]	Cow[3]
Average daily gain (ADG, kg/day)	909	938	0.83 (0.20)	0.91 (0.19)	-
Metabolic body weight (MBW, $kg^{0.75}$)	909	938	19.81 (4.77)	26.14 (4.76)	-
Metabolizable energy intake (MEI, Mcal)	4,458	938	5.50 (1.63)	5.78 (1.42)	-
Phenotypic residual feed intake (RFI, kg/day)	7,910	474	-	-	0.29 (2.76)

[1]Pre-weaning period (day 5-28 of life)
[2]Peri-weaning period (day 40-60 of life)
[3]First parity cow (week 9 to 44 of lactation)

Table 2. Heritability (diagonal), genetic correlation (above diagonal) and phenotypic correlation (below diagonal) among PreW calf and first parity cow feed efficiency traits.

	ADG	MBW	MEI	RMEI	RFI
ADG	0.13 (0.03)	0.73 (0.07)	0.87 (0.07)	0	0.51 (0.20)
MBW	0.97 (0.06)	0.36 (0.06)	0.68 (0.07)	0	0.39 (0.17)
MEI	0.85 (0.08)	0.78 (0.06)	0.26 (0.05)	0.28	0.15 (0.19)
RMEI	0	0	-0.39	0.17	-0.65
RFI	-0.14 (0.15)	-0.07 (0.12)	0.01 (0.13)	-0.35	0.27 (0.05)

Table 3. Heritability (diagonal), genetic correlation (above diagonal) and phenotypic correlation (below diagonal) among PeriW calf and first parity cow feed efficiency traits.

	ADG	MBW	MEI	RMEI	RFI
ADG	0.14 (0.03)	0.71 (0.08)	0.78 (0.11)	0	0.55 (0.21)
MBW	0.98 (0.06)	0.37 (0.06)	0.54 (0.12)	0	0.42 (0.18)
MEI	0.48 (0.10)	0.37 (0.09)	0.41 (0.06)	0.74	0.73 (0.24)
RMEI	0	0	0.41	0.11	0.48
RFI	-0.17 (0.14)	-0.07 (0.12)	-0.18 (0.12)	0.34	0.28 (0.05)

RFI and calf RMEI likely reflect differences in gastrointestinal function at different life stages, as PreW calves behave as pseudo-monogastric animals and primarily consumer milk replacer, whereas PeriW calves consume solid feed and have more mature rumen function (Meale *et al.,* 2017). Hermisdorff *et al.* (2026) reported a moderate negative genetic correlation (-0.44 ± 0.33) between PreW-RMEI and PeriW-RMEI, highlighting how differences in gastrointestinal function affect feed efficiency across life stages.

Breeding value correlations were favourable between PreW-RMEI and heifer fertility traits, and between PeriW-RMEI and lactation persistency, methane efficiency, and mastitis resistance traits (Table 4). Feed efficient PreW calves may require less energy for maintenance, allowing greater allotment for growth and puberty to improve reproductive benchmarks (Bach *et al.,* 2021). Growing cattle who are feed efficient produce less methane, suggesting that the mechanisms underlying methane efficiency could be present in the PeriW period (Callegaro *et al.,* 2022). The favourable relationship between PeriW-RMEI and mastitis resistance indicates lower somatic cell scores in feed-efficient PeriW calves, and may also explain the complimentary relationship with lactation persistency, as mastitis can severely disrupt lactation curves (Capuco *et al.,* 2003).

Table 4. Correlations of relative breeding values for PreW-RMEI and PeriW-RMEI with milking, environmental, reproduction, and mastitis resistance traits for sires with 5 or more phenotyped daughters (n = 56). (Standard errors ranged from 0.10 to 0.14).

		PreW-RMEI	PeriW-RMEI
Milking	Lactation Persistency	-0.21	0.57*
Environmental	Methane Efficiency	-0.26	0.36*
Reproduction	Age at First Service	0.27*	-0.02
	First Service to Conception (Heifers)	0.43*	0.02
	Non-Return Rate (Heifers)	0.30*	-0.03
Mastitis Resistance	Somatic Cell Score	-0.42*	0.59*
	Mastitis Resistance	-0.38*	0.53*

*Significant using two tailed t-test (α=0.05)

Conclusions

This study was used to estimate genetic parameters for RMEI as a calf feed efficiency trait and to investigate the genetic correlations with first parity cow feed efficiency. PreW-RMEI and PeriW-RMEI exhibited contrasting genetic correlations with first parity cow RFI, with PeriW-RMEI showing potential as an early-life indicator for cow feed efficiency. Breeding value correlations were favourable between PreW-RMEI and heifer fertility, and between PeriW-RMEI and lactation persistency, methane efficiency, and mastitis resistance. Future research should utilize data from multiple herds to validate study findings.

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