Spaans, O., van Elzakker , P., McNaughton, L., Spelman, R. (2026) Feed intake phenotypes of growing dairy heifers that are the progeny of bulls with high or low breeding values, *Proceedings 13th World Congress on Genetics Applied to Livestock Production* 24553:
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Feed intake phenotypes of growing dairy heifers that are the progeny of bulls with high or low breeding values

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Introduction

It is important to consider feed efficiency when breeding for dairy cows that emit less methane (CH_4), as the amount of feed eaten is related to CH_4 emissions. Enteric CH_4 is a source of digestible energy loss, suggesting that more feed efficient animals would produce less CH_4 (Waghorn and Hegarty, 2011). Two key efficiency metrics are residual feed intake (RFI) and feed conversion efficiency (FCE), both of which incorporate dry matter intake (DMI) and liveweight (LW) gain to assess the amount of feed eaten that is used for growth in slightly different calculations. As the first metric assessed herein, RFI quantifies the difference between an individual's actual DMI and predicted DMI required for maintenance and production, using regression methods, with low RFI animals being more efficient as they require less intake than their energy requirements (Berry and Crowley, 2013; Pryce *et al.,* 2014; Waghorn and Hegarty, 2011). The second metric, FCE, is a ratio trait that is calculated with the actual DMI and LW gain, to assess the conversion of nutrients consumed to the product, with high FCE animals being more efficient as they convert more feed to growth (Pryce *et al.,* 2014; Smith *et al.,* 2021). Although similar information is used to calculate these metrics, they are different traits. There are conflicting reports of the relationship between CH_4 production and feed efficiency metrics whereby, improved efficiency has resulted in reduced emissions in some studies, but increased emissions in others. For example, Flay *et al.* (2019) reported young dairy heifers of low RFI (i.e., improved efficiency) had greater CH_4 yield than heifers of high RFI, but no difference in daily CH_4 production between the groups. On the other hand, Hailemariam *et al.* (2021) compared groups of high and low RFI lactating Holstein cows and reported lower daily CH_4 production for the low RFI cows and no difference in CH_4 yield between groups of high and low RFI cows. Overall, this indicates there are complex relationships between energy consumed and partitioned into growth and maintenance, or lost as a waste product (i.e., CH_4 emissions). Therefore, the objective of this study was to compare the phenotypic RFI and FCE of growing dairy heifers with high or low CH_4 yield.

Materials & Methods

Experimental Design. Approval for all animal experiments was granted by the AgResearch Animal Ethics committee (#15176 and #15533 for bulls and #606 and #2354 for heifers). Dairy heifers (n = 396) of 6 to 15 months of age were measured for DMI and LW in an indoor facility as part of a study on the CH_4 emissions of growing heifers sired by bulls with divergent CH_4 estimated Breeding Values (metEBV; Spaans *et al.*, 2026) which were the top and bottom 5% of bulls for metEBV measured to date in 2022 (n = 491). Breed of heifers were predominantly crosses of Holstein-Friesian and Jersey. Heifers were blocked by LW in March 2024, sire metEBV group, and breed, then allocated to one of four lots that were measured for 39 days each, with the first 7 days treated as an adaptation period. In each lot, heifers were allocated to one of 8 pens that were balanced for high and low metEBV sire and LW. Alfalfa hay cubes (Multicube Stockfeeds, Yarrawong, Vic, Australia), were offered *ad libitum*, with individual intake measured by Hokofarm RIC2Discover bins (Emmeloord, Netherlands). Methane emissions were measured using GreenFeed (C-Lock, Rapid City, USA), with one GreenFeed

per pen. Concentrate pellets (CRV Youngstock Blend, SealesWinslow Ltd., Morrinsville, New Zealand) were used as an attractant in the GreenFeed units to measure CH_4 emissions, with the daily DMI of these pellets also calculated and added to the daily DMI of alfalfa hay cubes to give a daily total DMI for each heifer. Liveweight was measured three times per week in the morning for the duration of the indoor trial.

Statistical analyses. Linear regression was used to describe the relationships between the daily total measured DMI and day of trial, and LW and day of trial for each heifer. Subsequently, the respective equations were used to predict DMI and LW at the midpoint of the experimental period (day 20) to estimate an individual average DMI and LW, with the slope equal to the average daily LW gain (LWg), and the average LW used to calculate metabolic LW ($LW^{0.75}$). The DMI predicted at the midpoint for each heifer was used as the average DMI for the RFI and FCE calculations. The RFI for each heifer was obtained by regression of the average DMI against $LW^{0.75}$ and LWg, and the FCE calculated by dividing the LWg by the average DMI. The effect of metEBV group on each variable of RFI, FCE, DMI, LW and LWg were analysed by use of mixed models. In each model fixed effects of proportion of Holstein-Friesian breed (0 to 16) and lot (1 to 4) of the experiment the heifer was measured in, and a random effect of pen number (1 to 8) were included (Spaans *et al.*, 2026). The least squares means of CH_4 production and CH_4 yield were previously presented in Spaans *et al.,* (2026). Briefly, these variables were analysed using a repeated measures mixed model, with the interaction of metEBV group and week of trial, fixed effects of proportion of Holstein-Friesian breed and lot, and pen number as a random effect. Partial Pearson correlation coefficients were calculated using the fitted values per heifer from each mixed model for RFI, FCE, CH_4 production and CH_4 yield, and the lot of the experiment used as the controlling variable.

Results & Discussion

Feed efficiency should be a key consideration when breeding for low CH_4 emitting cattle. Although the amount of feed consumed drives CH_4 production, and it has been suggested that improving feed efficiency would lower emissions (Waghorn and Hegarty, 2011), there are a multitude of other interactions that indicate it is not a simple linear relationship. The results presented herein aid to illustrate the complexity of these interactions, as the group of heifers which, on average, produced less CH_4 were not always more feed efficient.

The current study examines feed efficiency traits of growing, non-lactating heifers which were bred from young dairy sires of high and low metEBV (Spaans *et al.*, 2026). Briefly, the metEBV was calculated by adjusting genetic CH_4 production for the genetic variation in DMI (Handcock *et al.*, 2023) to select for animals that would emit more or less CH_4 per kilogram of DMI, i.e., high or low metEBV heifers. The heritability of metEBV in the young bulls was 0.08 (Handcock *et al.*, 2023) which did not change with the heifer data being added to the analysis. Overall, as growing non-lactating heifers, the low metEBV group had lower CH_4 production and CH_4 yield than the high metEBV group, with no difference in DMI or LW gain between the groups (Table 1; Spaans *et al.*, 2026). These results confirm that young growing heifers with lower CH_4 production could be bred from young dairy sires with low metEBV, without affecting DMI and growth. Therefore, we hypothesized that there would be no difference in feed efficiency metrics between the high and low metEBV heifer groups. Confirming our hypothesis, for both RFI and FCE there was no difference, on average, between the high and low metEBV heifer groups (Table 1, Figure 1). As presented in Figure 1A, there was a wide range in the RFI of both high and low metEBV heifers. Individual RFI for both groups ranged from -0.48 to 0.51 kg DMI/d (Figure 1A) with no difference in overall group means, of -0.01 kg DMI/d for the high metEBV heifers and 0.06 kg DMI/d for the low metEBV heifers (Table 1).

Table 1. Least squares means (LSM) and standard error (SE) of methane (CH_4) production, CH_4 yield, dry matter intake (DMI), liveweight (LW), liveweight gain (LWg), residual feed intake (RFI), and feed conversion efficiency (FCE) for groups of high and low methane estimated breeding value (metEBV) heifers.

	High metEBV		Low metEBV		
	LSM	SE	LSM	SE	*P*-value
CH_4 production (g/d)	171.4	1.38	166.7	1.55	< 0.05
CH_4 yield (g/kg DM/d)	18.4	0.13	17.6	0.15	< 0.001
DMI (kg/d)	9.95	0.140	10.10	0.144	0.15
LW (kg)	246	2.35	248	2.39	0.074
LWg (kg/d)	1.26	0.024	1.29	0.026	0.27
RFI (kg DMI/d)	-0.01	0.097	0.06	0.100	0.42
FCE (kg LW/kg DMI)	0.125	0.0026	0.126	0.0027	0.69

Similarly, the mean FCE of high and low heifer groups was not different, of 0.125 and 0.126 kg LW/kg DMI, respectively (Table 1). Individual heifer FCE values ranged from 0.11 to 0.15 kg LW/kg DMI and were spread across both groups (Figure 1B). Overall, there was a wide variation in the feed efficiency metrics for the low metEBV heifers, indicative of individuals that were both low CH_4 producers and feed efficient.

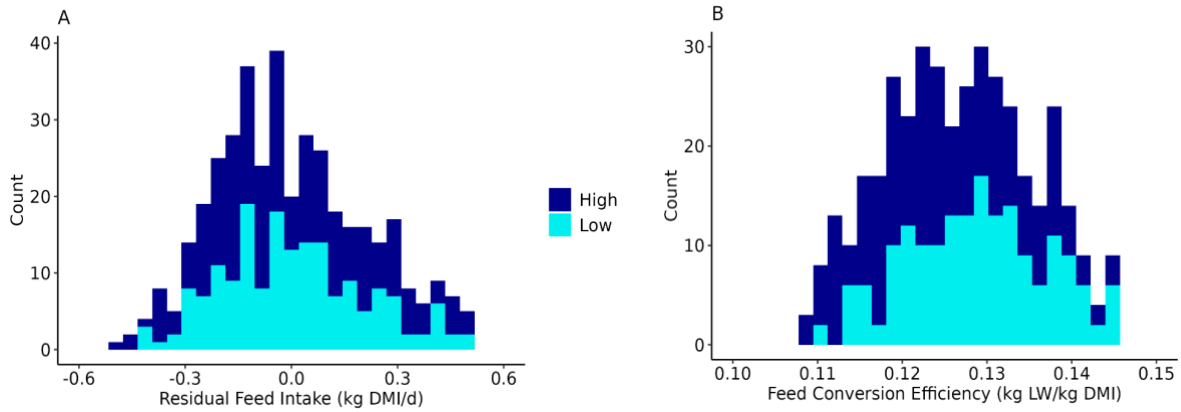

Figure 1. Histogram of the least squares means of (A) residual feed intake (kg DMI/d) and (B) feed conversion efficiency (kg LW/kg DMI) of high (dark blue) and low (cyan) metEBV heifers.

Overall, the lack of difference in feed efficiency metrics between groups of high and low metEBV heifers, underpins the complexity of CH_4 production from ruminants. Despite having lower CH_4 yield, there was no feed efficiency gained, on average, for the low metEBV group as they ate the same amount of feed and gained the same amount of liveweight as the high metEBV group. Although the calculation uses similar inputs, FCE is a different phenotype to RFI, with a moderate partial Pearson correlation coefficient of -0.57 ($P < 0.001$) between FCE and RFI in this dataset. This indicates that there is a considerable amount of variation due to other factors, confirming these are individual traits that should both be considered when selecting for low CH_4 emitting cattle. In addition, there was a near zero phenotypic correlation between CH_4 yield and RFI of -0.04 ($P > 0.10$), and a weak correlation between CH_4 production and RFI of 0.24 ($P < 0.001$). There were also weak correlations between FCE and CH_4 yield of -0.11 ($P < 0.05$) and between FCE and CH_4 production of -0.17 ($P < 0.01$). Together, these results indicate the lower CH_4 production of the low metEBV heifers was not driven by more

efficient use of feed and less waste product as CH_4. In a study of beef cattle with divergent residual CH_4 emissions, weak phenotypic relationships between CH_4 yield and FCE of 0.14, CH_4 yield and RFI of -0.24, CH_4 production and FCE -0.05 and CH_4 production and RFI of 0.23 were reported by Smith *et al.* (2021). Although the direction of the relationships is different to that presented in the current study, both sets of correlation coefficients confirm a weak relationship between each of the phenotypes. The results of the current study somewhat align with those of Hailemariam *et al.* (2021), who reported no difference in CH_4 yield between groups of lactating cows with divergent RFI. There was, however, lower CH_4 production and lower DMI for the low RFI group (Hailemariam *et al.*, 2021), supporting the concept of the amount of feed consumed driving CH_4 production, rather than the more efficient use of feed resulting in less CH_4 as a waste product. The results of Flay *et al.* (2019) would appear to be in contrast to this, whereby low RFI dairy heifers had similar CH_4 production to the high RFI heifers, but a lower DMI resulted in a greater CH_4 yield for the low RFI group. However, it is probable, as the authors highlighted, that the lower RFI trait in these heifers was a result of greater digestibility of DM and NDF in the rumen (Flay *et al.*, 2019), rather than the simple equation of metabolic efficiency resulting in less CH_4. This points to the mounting evidence of the role of the rumen microbiome as the major controller of CH_4 emissions (Gonzalez-Recio *et al.*, 2023), and which most likely contributes to the differences between metEBV groups.

Conclusions

Feed efficiency traits were compared in groups of high and low metEBV growing, non-lactating heifers. Although the low metEBV heifers produced less CH_4 compared with the high metEBV heifers, there was no difference between groups for DMI, LW gain, RFI or FCE. Therefore, lower CH_4 production of the low metEBV heifers was not driven by more efficient use of feed and less waste product of digestion as CH_4.

Acknowledgements

Funded by the Ag Emissions Centre (formerly New Zealand Agricultural Greenhouse Gas Research Centre; Palmerston North, New Zealand) as part of the Low Methane Cattle project.

References

Berry, D. P., and Crowley, J. J. (2013). J. Anim. Sci. 91:1594–1613. doi.org/10.2527/jas.2012-5862

Flay, H. E., Kuhn-Sherlock, B., Macdonald, K. A., Camara, M., Lopez-Villalobos, N., Donaghy, D. J., and Roche, J. R. (2019). J. Dairy Sci. 102: 2708–2713. doi.org/10.3168/jds.2018-15234

Gonzalez-Recio, O., Scrobota, N., López-Paredes, J., Saborío-Montero, A., Fernández, A., López De Maturana, E., Villanueva, B., Goiri, I., Atxaerandio, R., and García-Rodríguez, A. (2023). Animal, 17: 100780. doi.org/10.1016/j.animal.2023.100780

Hailemariam, D., Manafiazar, G., Basarab, J., Stothard, P., Miglior, F., Plastow, G., and Wang, Z. (2021). Canadian J. Anim. Sci. 101: 177–190. doi.org/10.1139/cjas-2019-0085

Handcock, R. C., Garrick, D. J., Garrick, D. P., Spelman, R. J., van Elzakker, P., Worth, G., and McNaughton, L. R. (2023). Proc 25th AAABG, Crawley, Australia.

Pryce, J. E., Wales, W. J., De Haas, Y., Veerkamp, R. F., and Hayes, B. J. (2014). Animal 8: 1–10. doi.org/10.1017/S1751731113001687

Smith, P. E., Waters, S. M., Kenny, D. A., Kirwan, S. F., Conroy, S., and Kelly, A. K. (2021). J. Anim. Sci., 99:1-13. doi.org/10.1093/jas/skab275

Spaans, O. K., Waghorn, G. C., Worth, G. M., Van Elzakker, P., Spelman, R. J., and McNaughton, L. R. (2026). J. Dairy Sci., 109: 2368–2382. doi.org/10.3168/jds.2025-26991

Waghorn, G. C., and Hegarty, R. S. (2011). Animal Feed Science and Technology, 166–167: 291–301. doi.org/10.1016/j.anifeedsci.2011.04.019