Milk mid-infrared indicators of intake, nitrogen efficiency, and methane across lactation

Maria Frizzarin, Elisa Manzocchi, Anna-Maria Reiche, Patrick Schlegel, Giovanni Lazzari, Marco Tretola, Fredy Schori, Frigga Dohme-Meier, Claudia Kasper.
Corresponding author: maria.frizzarin@agroscope.admin.ch
Agroscope, 1725 Posieux, Switzerland; www.agroscope.ch

Background

Dry matter intake (DMI), nitrogen use efficiency (NUE), and methane (CH_4) emissions are key sustainability traits in dairy production but remain difficult to measure at national level.

Milk mid-infrared (MIR) spectroscopy is:

- Routinely used worldwide for the quantification of fat, protein, and lactose,
- Already used to develop equations for milk characteristics (e.g. fatty acids) and animal characteristics (e.g. energy balance),
- Offers a low-cost phenotyping opportunity.

Objective

The objective of the study was to develop and evaluate MIR-based prediction models for DMI, NUE, and CH_4 in dairy cows, and to assess the biological validity of the predicted trait patterns along the lactation curve and across parities.

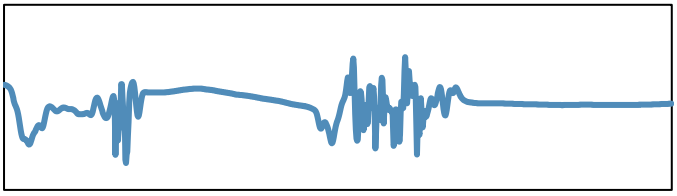


Figure 1. Milk mid-infrared spectrum of the milk

Materials and Methods

- Milk MIR spectra, feed intake, diet composition, and automated head-chamber methane measurements were collected at the Agroscope experimental farm in Posieux (2015–2024);
- NUE was calculated as milk nitrogen ÷ nitrogen intake, furthermore DMI and NUE were averaged across ±2 days and CH_4 across ±5 d of milk sampling to reduce trait variability;
- Three prediction models were tested: linear regression, partial least squares regression (PLSR), and neural networks (NN). Models were evaluated using 4-fold animal-independent cross-validation;
- The effects of lactation stage and parity on predicted DMI, NUE and CH_4 were analyzed using mixed-effects models.

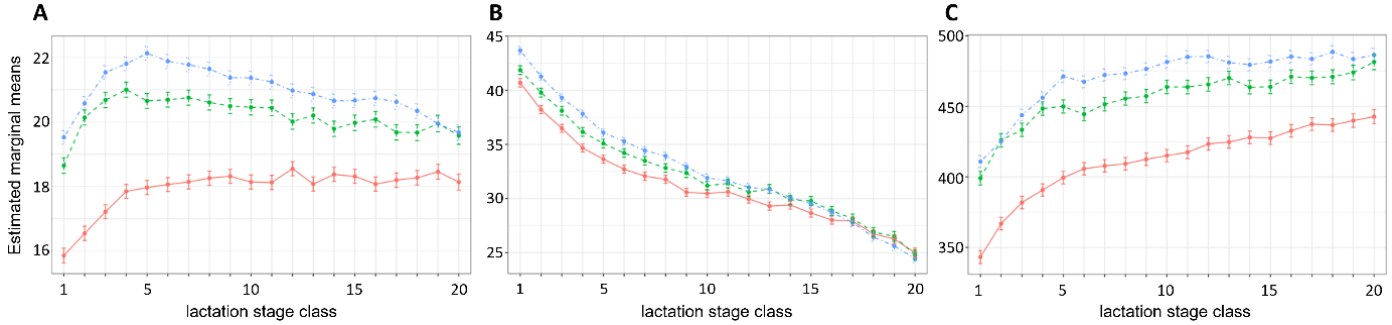
Results

NN consistently outperformed PLSR models ($P < 0.05$). Including MIR information improved prediction of DMI, NUE, and CH_4 compared with animal information alone ($P < 0.05$). Prediction accuracy was moderate (DMI: R^2=0.64; NUE: R^2=0.56; CH_4: R^2=0.52) and the best model for each trait was applied to 9,975 historical milk MIR spectra. The predicted traits reproduced biologically expected patterns along the lactation curve and across parities (Figure 2). Correlations between residuals were near zero for predicted NUE vs. DMI and NUE vs. CH_4, but moderate (0.44) between DMI and CH_4.

Summary

When prediction equations are applied to data collected in the same farm as the data used to develop the models, MIR spectroscopy captures meaningful biological signals and can provide scalable longitudinal indicators of feed efficiency and environmental impact. Therefore, if prediction equations are developed to cover as much as possible the variability of national dairy cow farming conditions, milk spectra represent a promising scalable phenotyping tool for individual monitoring and genetic improvement of sustainability traits in dairy production.

Figure 2. Estimated marginal means and standard error of the means for mid-infrared predicted dry matter intake (kg/d; A), nitrogen use efficiency (g/100 g; B), and methane production (g/d; C) in first (red), second (green), and third or greater (blue) parity cows along lactation stage classes (spanning 15 days; x-axis) in dairy cows.



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Federal Department of Economic Affairs, Education and Research EAER
Agroscope