

Predicting energy balance of Holstein-Friesian cows using mid-infrared spectrometry of milk

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Introduction

The main hindrance to the inclusion of energy status (ES) in multi-trait genetic evaluations as a predictor of health and fertility is the difficulty and expense of energy intake data collection on large numbers of animals. Recently, the mid-infrared spectrum (MIR) of milk, the method of choice worldwide to routinely predict milk composition, was proposed as an indicator of ES (McParland et al., 2011). The objective of this study was to test the robustness of the equations developed to predict ES across independent populations of indoor-fed and grazing Holstein-Friesian dairy cows.

Materials and Methods

Performance data collected between 1990 and 2011 from two separate research herds were used in this study; data from the Scottish Agricultural College research herd (SAC) and data from the Teagasc Moorepark research herd (MPK). The SAC herd comprised 1,218 cows divided into two dietary treatments, high concentrate and low concentrate. The MPK data set comprised 1,586 animals of differing strains of Holstein-Friesian on a predominantly grazed grass diet with periodic concentrate supplementation. Random regression models were fit, within parity, and within country, to routinely collected dry matter intake (DMI) (SAC only), milk production, body weight (BW) and body condition score (BCS) records to generate daily solutions for each trait and ultimately calculate ES for each day of lactations 1 to 4. Energy status was computed for MPK animals only during periods of lactation where actual DMI was recorded. Energy balance (EB; MJ/d), was computed as a function of milk yield, fat and protein content, DMI, BW and BCS. Energy content (EC; MJ) was computed as a function of BCS and BW predicting body lipid and protein weight. Morning (MPK(am)) and evening (MPK(pm)) milk samples from MPK animals were analysed weekly using a Foss MIR spectrometer. Morning (SAC(am)), midday (SAC(md)) and evening (SAC(pm)) samples from SAC animals were analysed monthly using the same MIR spectrometer. The Foss MIR spectrum contains 1,060 data points which represent the absorption of infrared light by the milk sample at wavelengths in the 900 cm⁻¹ to 5,000 cm⁻¹ region. Only spectral data with an actual phenotypic record for all component variables of EB within 7 days of the corresponding milk sample were retained. Spectral data were transformed from transmittance to linear absorbance through a log₁₀ transformation of the reciprocal. In total, 820 MPK(pm) and 844 MPK(am) spectral records from 244 MPK cows with EB data were available together with 2,989 SAC(pm), 2,992 SAC(am) and 2,742 SAC(md) records from 337 SAC cows.

Partial least squares regression was used to predict ES from the MIR linear absorbance data. Predictor variables included a subset of wavelengths from the spectrum of 1,060 correlated wavelengths, together with milk yield. All prediction equations were undertaken using am, md (where available), and pm samples, separately. Accuracy of all equations was tested using both split sample cross-validation and external validation. Two types of analyses were undertaken: 1) prediction equations were calibrated within the SAC data set and externally validated on the MPK data set, and 2) the two research data sets were combined and equations calibrated and validated using the combined data set. When equations were calibrated and externally validated using the combined data set, the data were sorted according to ES and every fourth record removed from the calibration data set for inclusion in the external validation data set. This was done to optimise the robustness of the prediction equation, since samples contained in the calibration data set should represent the variation observed in the phenotype to be predicted.

Results and Discussion

Prediction equations calibrated using data from SAC only, were not useful to predict either EB or EC of MPK animals. External validation accuracies ranged from 0 to a maximum of 0.15 for both sets of equations. The slope between true and predicted EB was close to 0 while the bias was greater than 40 MJ for all equations tested across research data sets. Similarly, the slope and bias between true and predicted values of EC was poor across all equations tested. Prediction equations developed using pooled data from SAC and MPK research data sets were more robust than equations tested across research data set. Combined prediction equations had an accuracy of prediction of EB of 0.69, and had a slope (se) from the regression of true on predicted values of EB of 0.98 (0.03), whilst the mean bias (se) between true and predicted values of EB was 1.12 (0.88) MJ. Very high accuracy of prediction was not expected given the inherent errors in calculation of "true" energy balance. The accuracy of prediction of EC was lower than that of EB, however was more robust when equations were tested across research data set.

Conclusion

Equations have been developed which give accurate predictions of energy balance across lactation using the MIR spectrum of milk. Although equations developed on one production system are not robust to predict energy balance of animals on a different production system, when a combined data set across production systems was used, results were greatly improved.

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