Predicting cow body energy status using mid-infrared spectrometry of milk

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Introduction

Cow body energy status is an important indicator of health and fertility in dairy cows, but is difficult to measure, primarily due to the cost of measuring feed intake. Mid-infrared spectrometry (MIR) is a tool used to routinely measure the fat and protein content of milk. The objective of this study was to attempt to predict the energy status of dairy cows using the MIR spectrum of milk.

Materials and Methods

Performance data collected between 1990 and 2010 on 1,145 research cows stationed at Crichton Royal Farm, Scotland were used. Random regression models were fit, within parity, to routinely collected dry matter intake, milk production, live weight and body condition score records to generate daily solutions for each trait. These solutions were used to calculate body energy status (EB; MJ) for each day of lactations 1 to 4 (Banos and Coffey, 2010).

Monthly between September 2008 and May 2010, three milk samples (representative of morning (AM), mid-day (MD) and evening milking (PM)) from each cow were analysed using an MIR spectrometer (Foss Milkoscan FT6000). The resulting MIR spectrum generated for each milk sample contained 1,060 data points representing the absorption of light through the milk sample in the 900cm^{-1} to 5,000cm^{-1} wavelength 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 $\log_{10}$ transformation of the reciprocal. A total of 1,883 AM, 1,731 MD and 1,855 PM milk spectra were retained for analysis.

Partial least squares analysis was used to relate the linear absorbance spectrum data to EB. Calibration and validation data sets were generated by randomly splitting the data in a ratio of 75% (calibration) to 25% (validation). This process was iterated 4 times so that 4 calibration data sets were generated to develop prediction equations and 4 validation data sets were developed to test the accuracy of prediction of the equations in independent data. Prediction accuracies were tested using both cross validation within the calibration data set (equations developed were tested on 5% of the calibration data set iteratively until all samples were predicted) and external validation within the validation data sets. Results presented are the average across all four external validation data sets. The maximum number of explanatory variables included in the models to explain EB was determined in response to the changes in accuracy of both cross validation and external validation when the number of factors was altered. Separate prediction equations were developed using AM, MD and PM milk samples. In a separate set of analyses, milk yield was added to the prediction models. The accuracy of predicting EB in early lactation (days in milk <61) was also tested. Finally, to test if the prediction equations developed were more accurate than fat to protein ratio (FPR) as a predictor of EB, the correlation between FPR and EB was also tested.

Results and Discussion

The average EB across the entire data set was -4.3 MJ (SD = 29.6). The correlation between milk FPR and EB was -0.09 across lactation and -0.28 in early lactation, thus FPR was a poor indicator of EB in this study, despite being suggested as a possible indicator (Heuer *et al*., 2000).

Accuracy of predicting EB across lactation using the MIR spectrum as the sole predictor was 0.72, 0.71 and 0.75 for AM, MD and PM milk samples, respectively, when tested using cross validation. The corresponding accuracy of prediction when tested using external validation on independent data was 0.68, 0.67 and 0.72 for AM, MD and PM milk samples, respectively. The regression coefficient between predicted and actual values of EB was not different from one (P>0.05) indicating that a one unit change in predicted EB was associated with a one unit change in actual value.

When milk was included as an additional explanatory variable in the model, the accuracy of prediction improved. The external validation accuracy of prediction was 0.70, 0.69 and 0.75 for AM, MD and PM milk samples, respectively. Improved accuracies of prediction were expected since milk yield was included in the calculation of EB and hence a statistical part-whole relationship between the two variables exists. A biological part-whole relationship also exists and since data on milk yield will be available at milk recording, its inclusion in the models is justified. Poorer accuracies of prediction were obtained for animals in early lactation. The accuracy of external validation was 0.59, 0.65 and 0.69 for AM, MD and PM milk samples, respectively. The data sets used to develop and test the equations in early lactation were smaller than across lactation and comprised 387, 353 and 384 records for AM, MD and PM samples, respectively.

Conclusions

The use of MIR spectrum data to predict EB shows great promise. Accuracies of prediction using this method were greater than the traditionally used FPR and offer a method of cheap and accurate predictions of cow body energy status through routine milk sampling.

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