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Limits to prediction of energy balance from milk composition measures at individual cow level

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ABSTRACT

Frequently updated energy balance (EB) estimates for individual cows are especially useful for dairy herd management, and individual-level estimates form the basis for group-level EB estimates. The accuracy of EB estimates determines the value of this information for management decision support. This study aimed to assess EB accuracy through ANOVA components and by comparing EB estimates based either on milk composition (EBalMilk) or on body condition score (BCS) and body weight (BW) (EBalBody). Energy balance based on milk composition was evaluated using data in which milk composition was measured at each milking. Three breeds (Danish Red, Holstein-Friesian, and Jersey) of cows (299 cows, 623 lactations) in parities 1 to 4 were used. Milk data were smoothed using a rolling local regression. Energy balance based on milk composition was calculated using a partial least squares (PLS) model based on milk fat, protein, and lactose contents and yields, and the daily change in these variables at each day. Energy balance based on BCS and BW was calculated from changes in body condition and BW scored weekly or fortnightly. Equations for calculation of EBalMilk and EBalBody used no common variables and were, therefore, assumed mathematically independent. Traits were analyzed within 3 stages of lactation expected to have high mobilization of body tissue (1, early), almost balanced (2), and deposition of body energy (3, mid to late lactation). In general, EBalMilk and EBalBody followed similar expected changes through lactation. Estimates of covariance were obtained using single-trait mixed models with random regression terms describing the change with time and used for calculation of repeatability as intraclass correlations. Within stage, EBalMilk was less repeatable than EBalBody (0.53, 0.41, 0.43 vs. 0.93, 0.91, 0.86, respectively, for stages 1, 2, and 3), mainly because of a larger residual variance for EBalMilk. Correlations between individual-level estimates of EBalMilk and EBalBody were close to zero. However, correlations between EB estimates in different lactation stages tended to be stronger for EBalMilk than for EBalBody, although correlations for both EB traits were small. It is concluded that EB estimates based on milk composition are less accurate than those based on body traits, but EBalMilk can compensate partly for this inaccuracy by being updated more frequently.
Key words: milk composition, energy balance, dairy cow, body condition

INTRODUCTION

Monitoring of cow status at the individual level has been shown to provide real benefits in terms of early identification of cows with health and reproductive problems (Friggens et al., 2007b; Friggens and Løvendahl, 2008). Given the central role of energy balance in the feeding–health–reproduction complex (Friggens, 2003; Ingvartsen et al., 2003), being able to predict energy balance at individual level would also be expected to be of great value to the dairy farmer. Unfortunately, measuring energy balance by classical input-output methods is not feasible on commercial farms because they do not measure individual feed intake. An alternative is to predict energy balance from milk composition measures (Grieve et al., 1986; Heuer et al., 1999, 2000, 2001; Reist et al., 2002). This method has recently been shown to be very accurate (R^2 > 94%; prediction error 3.8 MJ/d) for predicting breed-parity average energy balance through lactation from daily milk measures (Friggens et al., 2007c). However, Friggens and colleagues (2007c) also showed that there was a significantly poorer fit when the model was used to predict the energy balance of individual cows rather than group averages. The purpose of the present study was to characterize the between-cow variation in prediction of energy balance with a view to improving the prediction of energy balance at the individual cow level.

There are several potential reasons for the poorer fit of the prediction model when applied at the individual cow level. It is, of course, to be expected that

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the goodness of fit of average data would be better than that of individual data simply on the grounds of the reduction in error that averaging provides. However, there could be other, biological, reasons for individual cow deviations from the average. It has been shown that there is genetic variation in both milk composition measures (Vos and Groen, 1997) and energy balance (Coffey et al., 2001; Banos et al., 2005b; Oikonomou et al., 2008a,b). Genetic correlations between energy balance and milk measures are somewhat less than 1 (e.g., Coffey et al., 2001), indicating that there may be real (genetic) variation between individuals in the relationship between milk measures and energy balance that we wish to model. Modeling this variation could lead to an improvement in prediction of individual energy balance from milk measures. A second possible source of animal deviations could be caused by variation between individuals in the conversion factors between the measures used and the energy equivalent of those measures. With regard to milk composition, these conversion factors are the energetic efficiencies for producing milk fat, protein, and lactose (and their energy contents). Previous studies indicate that individual variation in these efficiencies is rather small (Veerkamp et al., 1995). There is, however, another set of variables and associated conversion factors used to generate the model for predicting energy balance; the "y" variables used in the partial least squares (PLS) regression from which the predictive equation was developed, namely BW and BCS. The conversion factors associated with these variables are those that convert BCS to body fatness and adjust BW for gutfill. These factors could equally be subject to individual variation. For this reason, individual variation associated both with energy balance predicted from milk measures (**EBalMilk**) and energy balances calculated from body changes (**EBalBody**) were explored.

An additional aspect explored in this study is how the individual deviations change with time from calving. These time trends may shed light on both sources of variation described above and on potential additional parameters to be included in an improved model to predict energy balance at the individual level.

MATERIALS AND METHODS

Experiment Design and Records

The data used were collected within a 5-yr experiment conducted from October 1996 to October 2001 at the Danish Cattle Breeders Organization research farm Ammitsbøl Skovgård. All the procedures involving animals were approved by the Danish Animal Experiments Inspectorate and complied with the Danish Ministry of Justice Law no. 382 (June 10, 1987) and Acts 739, (December 6, 1988) and 333 (May 19, 1990) concerning animal experimentation and care of experimental animals.

The design and methods for the production aspects of the experiment have been described in detail elsewhere (Nielsen et al., 2003). Briefly, 3 breeds were represented: Danish Holstein, Danish Red, and Jerseys. The design included 2 genetic lines within each breed. For Danish Red and Danish Holstein, the 2 lines were selected solely for milk yield or dual-purpose milk and meat production. The 2 Jersey lines were Danish Jerseys and American Jerseys. A summary of the performance of the different breeds and lines has been presented by Nielsen et al. (2003). Within all levels of genetic structure, cows were equally assigned to 1 of 2 dietary treatments. The cows were studied during consecutive lactations and remained on the same dietary treatment throughout. The cows were housed throughout the year in single tie stalls. Records of 623 lactations from 299 cows were available. The number of lactations in each parity was 269, 226, and 128 for parities 1, 2, and 3+, respectively.

The cows were fed 1 of 2 TMR ad libitum throughout lactation. The normal energy diet (**NTMR**) was designed to allow the cows to meet their energy requirements. The low energy diet (**LTMR**) was designed to limit feed energy supply. The composition of the 2 TMR was fixed irrespective of stage of lactation. The average digestible energy contents of NTMR and LTMR were 13.55 and 12.88 MJ/kg of DM, respectively. The average CP contents of NTMR and LTMR were 153 and 145 g/kg of DM, respectively. The average dry matter intakes of Danish Holstein cows on NTMR and LTMR were 20.8 and 20.1 kg/d, respectively. The average 305-d milk yields of Danish Red, Danish Holstein, and Jersey cows on NTMR were 6,060, 7,242, and 5,081 kg, respectively (Friggens et al., 2007a).

The cows were milked twice daily. Milk yield and milk composition were recorded at each milking. Proportional milk samples taken from each milking were analyzed for fat, protein, and lactose. All animals were weighed on d 2, 3, and 8 after calving and then once weekly until 3 mo after calving. From 3 mo after calving to the dry period they were weighed fortnightly. During the dry period, the cows were weighed once weekly. To minimize the influence from milking and feeding, the cows were weighed at the same time of day. Body condition was scored to the nearest half unit on the Danish scale (Kristensen, 1986; derived from Lowman et al., 1976) from 1 to 5 on d 2, 14, 28, 42, 56, 84, 112, 168, and 224 after calving. Additionally, BCS was recorded on the day of drying off, d 35, 21, and 7 before expected calving, and finally on the day of calving. All BCS were