SELECTION FOR ENERGY BALANCE IN DAIRY COWS

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INTRODUCTION

The use of body lipid as a nutritional buffer is normal in mammalian lactation and some mammals lose up to 50% of their body weight during lactation. This maternal investment in the current offspring must be balanced against long term repeated reproductive success. Animal subsequently replace lost body tissue to achieve that long-term objective. Body lipid reserves are used to sustain early lactation since incremental feed intake can only account for a proportion of incremental milk energy output energy in high yielding cows. The term energy balance is often used to describe the daily body energy state of dairy cows; negative energy balance is associated with body energy loss and positive energy balance with body energy gain. Cows which lose body tissue, and hence energy, in early lactation usually return to positive energy balance at around 40 to 80 days *post partum* (Coffey *et al.,* 2001; Veerkamp *et al.,* 2000). However, cumulative body energy loss in the first lactation is, on average, only fully recovered at around day 200 (Coffey *et al.,* 2001). Negative energy balance is related to some health traits (Collard *et al*., 2000), to resumption of reproductive activity (Veerkamp *et al.,* 2000) and to oocyte size and quality (Kendrick *et al*., 1999). Individual cows may not regain all lost body energy in the first lactation, leading to a greater deficit to be replenished in the second. The replenishment of body lipid reserves usually occurs later in lactation once pregnancy is established, in preparation for the next lactation. So it forms a part of the complex of competing systems making demands for available nutrients. The outcome of this 'competition' creates a cyclical energy balance profile that spans lactations. Parameters of this cycle may be suitable selection criteria for future selection of robust cows since they have a biological interpretation. The phase relates to the period from calving to return to positive energy balance and the amplitude relates to the degree of body energy loss (Coffey et al., in press). The objectives of this work were to 1) calculate energy balance for individual cows over 3 successive lactations and 2) calculate energy balance breeding values for bulls for each day of the first lactation using field data.

MATERIAL AND METHODS

Analyses were conducted on data from the Langhill Dairy Cattle Breeding Centre where cows were part of a 3 lactation feed intake trial and also on national data taken as part of a conformation assessment scheme. Variance component estimation was performed using a random regression model with the ASREML statistical package.

Langhill data

Data for all animals were extracted from the database of Langhill records collected since 1990. The data included records of milk production and composition, liveweight (LWT), condition score (CS) and feed intake (FI) for two lines of cows. As pedigree information was not included in the analysis, animal solutions are combined animal genetic and permanent environmental effects. The random regression model fitted in this study was:

$$y_{it} = F_{it} + \sum_{m=0}^{f-1} \beta_m P_m(t) + \sum_{m=0}^{k-1} \lambda_{im} P_m(t) + \varepsilon_{it}$$

where F_{it} represents fixed effects of genetic line (2 groups), feed group (2 groups) and time of measurement (year and week of measurement) and the covariates percentage North American Holstein genes (linear) and age at calving in months (linear and quadratic). β_m are the fixed regression coefficients, λ_{im} are the random regression coefficients associated with the animal plus its permanent environment and ε_{it} is the residual error associated with days since calving *t.* $P_m(t)$ is the m^{th} Legendre polynomial evaluated at *t* and the parameters *f* and *k* are the order of the fixed and random polynomials respectively. Animal solutions obtained from the analysis were used to calculate daily phenotypic values for all animals, for all traits for days of lactation 1 to 305. Energy balance was derived in two different ways for the same cows after converting all measures to energy equivalents in order to assess the value of using body measurements obtained from field data to calculate EB. The first method (EB1) was based on predicted energy available from recorded feed consumption minus energy required for recorded daily milk production and maintenance predicted from LWT and gut fill. The second method (EB2) used body protein and lipid changes predicted from LWT and CS.

A visual appraisal of energy balance curves over 3 lactations for individual cows suggested that the fluctuations across lactations might be described by using sinusoidal functions. Cows calved at approximately 12 month intervals in the trial, so energy balance cycles about every 365 days. As cows regain body condition after calving at different rates, (*i.e.* the phase varies between cows), and cows have different total amounts of body energy loss, (*i.e*. the amplitude varies between cows), sinusoidal functions were associated with individual cows and allowed to vary between cows. The model for the harmonic analysis of the data was:

$$y_i = a + bT + c_i Sin(\frac{2\pi T}{365}) + d_i Cos(\frac{2\pi T}{365}) + e_i$$

where y_i = energy balance for animal *i* on day T (either EB1 or EB2), T = days since first calving, a and b are fixed regression coefficients which cater for a trend over time, c_i and d_i are the random regression coefficients and e_i = error term for animal *i*.

National data

A formula for predicting liveweight from linear type scores was deduced from 437 heifer records. After testing all traits for significance of fit, the best model for predicting liveweight taken at the same time as type assessment accounted for 73.6% of the variation and was:

$$lwt = pch + aai + Ang + CW + BD + Sta + RA + \varepsilon$$

where pch = percentage North American Holstein genes, aai = age at inspection , Ang = Angularity, CW = Chest Width, BD = Body Depth, Sta = Stature, RA = Rump Angle and ε is an error term. The national conformation assessment scheme operated by HUKI collects information on 16 linear type traits and a number of management traits. CS has been included in the scheme since 1996. Data were extracted for all heifer daughters of progeny test bulls and

11 widely used sires scored for CS since 1997. The random regression model fitted for national data was;

$$y_{it} = F_{it} + \sum_{m=0}^{f-1} \beta_m P_m(t) + \sum_{m=0}^{k-1} \alpha_{im} P_m(t) + \sum_{m=0}^{k-1} \lambda_{im} P_m(t) + \varepsilon_{it}$$

where F_{it} represents fixed effects of bull type (progeny test or widely used), classifier visit (year/week and herd of measurement) and the covariates percentage North American Holstein genes (linear) and age at calving in months (linear and quadratic). β_m are the fixed regression coefficients, α_{im} and λ_{im} are the additive genetic and permanent environmental random regression coefficients and ε_{it} is the error associated with time *t.* There were 58,567 daughters from 1250 bulls with a minimum of 10 daughters each represented in the dataset.

RESULTS AND DISCUSSION

Langhill data

Cows returned to positive energy balance at days 72, 75 and 95 in lactations 1, 2 and 3 respectively based on energy balance calculated from feed intake and milk output records (EB1, Figure 1), and at days 77, 83 and 73 based on energy balance calculated from body energy state changes (EB2). Differences in return to positive energy balance between EB1 and EB2 were non-significant in lactations 1 and 2, but significant in lactation 3. Correlations between energy balance at the same time in successive lactations ranged from 0.01 to 0.66 depending on the method of calculation and the stage of lactation.

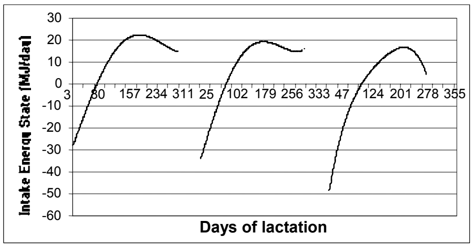

Figure 1. Three lactation energy balance using EB1

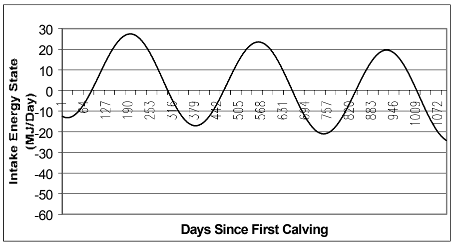

Figure 2. Three lactation energy balance using EB1 with sinusoidal fitting

The sinusoidal functions fitted to the curve removed a significant proportion of the variation but accounted for only 45% and 40% of the variation in EB1 and EB2 respectively. The fitted sin/cosine curve for all cows for 3 lactations using EB1 is given in Figure 2.

National data

Cumulative energy balance in the first lactation is given in Figure 3 for the highest and lowest 2 bulls for PIN (a UK profit index for production) with the highest number of daughters.

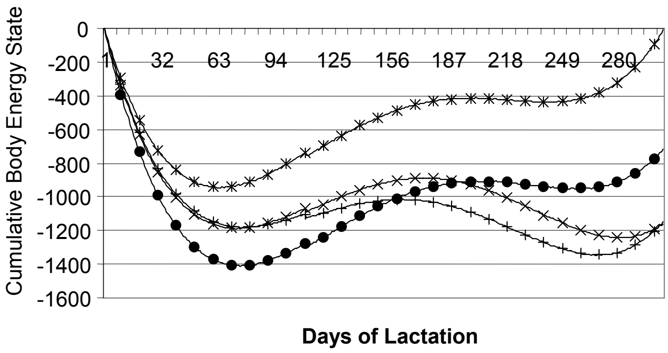

Figure 3. Cumulative energy balance for 4 bulls. (x and + are low PIN bulls and * and ● are high PIN bulls)

CONCLUSION

The relationship between energy balance in the first 3 lactations is more complex than a simple linear function but the profile of energy balance over the first 3 lactations may be a useful selection criteria in a multi-trait index. Energy balance profiles over lactations 1 to 3 can be modelled with moderate accuracy using sinusoidal functions and warrants further investigation. Energy balance profiles differ between bulls and may provide an additional selection criteria in the future since energy balance is associated with a number of health and fertility traits.

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