Selection for Energy Balance in Dairy Cows

M. P. Coffey [a]***, G. Simm*** [a]***, W. G. Hill*** [b]***, and S. Brotherstone*** [a]

[a] *Sustainable Livestock Systems, SAC, Bush Estate, Penicuik, Midlothian, EH26 0PH, UK*

[b]*ICAPB, School of Biological Sciences, University of Edinburgh, West Mains Road, Edinburgh, EH9 3JT, UK*

Introduction

Condition scoring is a technique for estimating the fat content of dairy cows. It relies on visual appraisal of the tailhead area and, optionally, tactile palpation of the loin area. There is a strong relationship between body condition score (BCS) and the fat content of cows (Fox *et al.,* 1999) making BCS a useful management and research tool for assessing fat content and its change.

In high-yielding dairy cows, the peak of daily feed intake usually occurs after the peak of milk output. This disassociation in timing leads to a period in early lactation when cows cannot meet their energy requirements solely from ingested feed energy and they mobilise body energy to meet the deficit. This state is commonly known as negative energy balance (NEB) and is negatively associated with a range of health traits (Collard *et al.,* 2000; Gillund *et al.,* 2001) and fertility (Veerkamp *et al.,* 2000; Wathes *et al.,* 2002; Dechow *et al.,* 2002). It can generally be considered to be undesirable not only for its direct economic cost but also for its potential effect on the health of the cow from a welfare viewpoint (Nielsen *et al.,* 1998). Selection indices may have favoured bulls whose daughters use body lipid in early life at the expense of production, health and fertility in later life. This has created increasing interest in BCS in dairy cows both as an important management tool and also for use in selection indices. A number of countries (including the UK, Netherlands and Ireland) now collect BCS as part of a national type assessment scheme.

A method of capturing BCS measures more easily and remotely would provide a number of benefits for a wider range of stakeholders. Images could be stored for identification purposes and as an audit trail of herd health and could be used in an integrated monitoring system that automatically collects data from a dairy system. An expert management system, running on an on-farm PC using these data, could react proactively to prevent health disorders and adjust management parameters accordingly. These data could then be transferred to a central store for processing into genetic evaluations. This would provide large volumes of objective and low cost data on body energy state changes in dairy cattle.

The aims of this study were a) to determine the feasibility of capturing shape data from digital images of dairy cows that could be related to BCS and b) to use BCS and LWT to calculate daily energy balance and hence investigate body energy changes over three successive lactations in high and average genetic merit cows on high and low concentrate diets.

Materials and Methods

Capturing shape data

This objective required the acquisition and analysis of pictures of cows taken from the rear using a commercially available digital camera (3.4 mega-pixels). All pictures were taken following routine milking once the cow had left the parlour. Pictures had to be taken quickly to prevent a backlog of cows creating a hazard for other cows leaving the parlour. The camera was activated using a remote control. Structured red laser light (wavelength 650nm) was used to create light lines across the area of interest of the cow. It was provided by a 10 milli-watt laser diode module feeding an integral holographic element that split the beam into ten equally-spaced lines. Out of 190 cows, only 36 images were suitable for data extraction due to blurring of images. Curves were extracted after software enhancement of the image and were identified using image editing software and a mouse to isolate the lines. At the same time cows were scored for body condition by a skilled operator on a 0 to 5 scale in quarter point intervals.

Energy balance

Data were extracted for all cows in lactations 1 to 3 from the database of Langhill records collected from 1990 until July 2002. At this point, the trial to record feed intake used in this study was terminated and the dataset consisted of animals that had a range of lactations completed under the trial up to lactation 3. The data included records of milk production and milk composition, liveweight (LWT), BCS and fresh feed intake (FI) for two lines of cows. These lines have been continuously selected either for kg fat plus protein (select line (S)) or to remain close to the average genetic merit for fat plus protein production for all animals evaluated in the UK (control line (C)). Approximately equal numbers of S and C cows were housed together and offered either a high or a low concentrate diet in the form of a total mixed ration (TMR) either for a minimum of 26 weeks or a maximum of 38 weeks of each lactation. There were 501 cows in the dataset that had at least one lactation with feed intake records. Where animals had at least three lactations with feed intake records there were 69 and 64 control cows in the low concentrate and high concentrate groups respectively. For the select cows there were 97 and 93 cows in the low concentrate and high concentrate groups respectively. Variance component estimation was performed using the ASREML statistical package with a multivariate random regression model. Since pedigree information was not included in the analysis, animal solutions are combined animal genetic and permanent environmental effects. Fixed regressions, which model the general shape of the curve and are common to all animals, were fitted for all traits as polynomials of order five based on previous analyses of similar data. Fourth order polynomials were used to model the animal genetic plus permanent environment effect.

Daily solutions for days of lactation 4 to 305 obtained from the analysis were used to calculate daily values on the phenotypic scale for all cows in the dataset, for all traits. Energy balance was derived using predicted body protein and lipid changes (EB) after converting all measures to energy equivalents. Energy used for maintenance and activity that was dependent on both feed composition and liveweight was included. Details of the formulae used to convert to effective energy equivalents are given by Coffey *et al.* (2001). The method of calculating daily body lipid content relies on an estimate of gut fill predicted from feed intake and feed composition. The feed composition was analysed weekly and occasionally the change in composition was sufficient to cause a large change in predicted body lipid content from one day to the next at the boundary of the change in feed composition. Therefore, when body lipid or body protein changed by more than 1.5kg the daily change was set to be the same as the day before to smooth out large fluctuations in body energy change that were an artefact of the calculation method.

The effect of the weight of the conceptus (foetus plus placenta plus fluid) on the prediction of empty body weight were accounted for in part by modelling conceptus total weight using an exponential growth curve from day of conception (ARC*,* 1980). The parameters of this curve were adjusted to predict a weight of gravid uterus at 281 days of gestation of 71, 78 and 85kg respectively for lactations 1 to 3, to account for assumed increases in weight of 10% per lactation for this component in larger and older cows. The daily predicted weight of conceptus was subtracted from empty body weight to reduce any upwards bias on body lipid estimation by the presence of conceptus. The daily predicted weight of conceptus was assumed to be constant for all cows of the same parity.

Results

Capturing shape data

An example of an image from which shape data were extracted is given in Figure 1. The curvatures of the tail head and the buttock were correlated with the condition scores strongly enough to show the correlation between shape and condition, but not strongly enough to reliably predict the condition score from the shape. For the tail head, the correlations obtained using the mean or median of all curves or the curve over the pin bone were similar at 55 to 58% (Figure 2), probably because the curvature did not vary much down the length of the cow. The mean also had a 56% correlation with the visual assessments, so the mean appeared to be the most reliable method. For the buttock the stripe over the pin bone gave the best correlation to the condition score (52%).

Figure 1. Software enhanced example image.

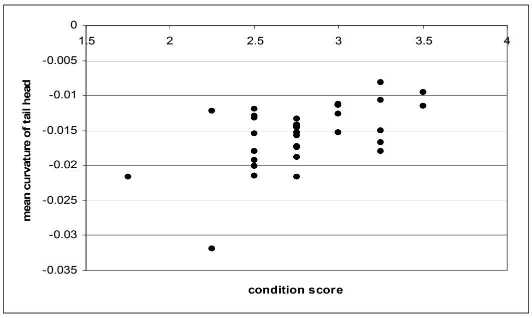

Figure 2. Scatter plot of tailhead curvature against CS.

Energy balance

As expected, the S cows on the high concentrate diet had the highest daily yield. The S cows on the low concentrate diet produced more milk than the C cows on the high concentrate diet and the difference between these two groups was most pronounced in the third lactation. Whilst S and C cows on each diet had yields throughout lactation that were different, the yield of S cows irrespective of diet and C cows irrespective of diet were similar at the end of lactation. This would appear to be due to the lactation for C animals being more persistent than that of the S animals. Fresh feed intake was greatest for S cows on the low concentrate diet and S cows had a higher feed intake on both diets than C cows. The difference between the groups in daily fresh feed intake was greatest in the third lactation. Select cows were also heavier by 44kg ($p < 0.005$) at the start of each lactation (Figure 2a) and lost more weight than C cows. All groups were of approximately equal weight at the end of each lactation. Select cows were of significantly higher BCS (Figure 2b) at the start of the first lactation ($p < 0.005$) and significantly lower BCS by day 18 of lactation 2 and day 12 of lactation 3 ($p<0.005$). Select cows lost more body condition at the end of the third lactation (0.53 BCS units and 0.46 BCS units) than C cows for high and low concentrate diets respectively ($p<0.005$). Select cows on a low concentrate diet had the lowest BCS at the end of the third lactation and had lost the greatest amount of body condition (0.54 BCS units).

The average daily energy balance is given in Figure 2c. Cows have a NEB of about 50, 75 and 125 MJ day in early lactation in lactations 1, 2 and 3 respectively. Figure 2d shows the cumulative body energy content (lipid and protein) from first calving. The effect of diet was significant for both genetic groups and all groups became significantly different for cumulative body energy content by day 15 of lactation 1. However, C cows were not significantly different from each other after day 45 of lactation 1. Select cows had significantly less ($p<0.005$) body energy than C cows throughout the 3 lactations and S cows on a high concentrate diet had significantly less ($p<0.005$) body energy than S cows on a low concentrate diet after day 6 and throughout the 3 lactations. The biggest difference in body energy content at the end of the third lactation was 3206 MJ and occurred between the S and C cows on the low concentrate diet.

Discussion

Shape information relating to BCS can be extracted from digital images of dairy cows but using the methods developed so far, only with limited accuracy. Not all of the information contained in BCS is available in digital images alone but some can additionally be obtained from normal farm recording systems e.g. milk yield. Additional information on body fat content might be derived from images taken at more than one place on the cow. Further research into automated body fat assessment from digital images is warranted with a view to constructing an integrated dairy cow monitoring system in order to improve cow welfare and reduce the environmental impact of dairy production systems.

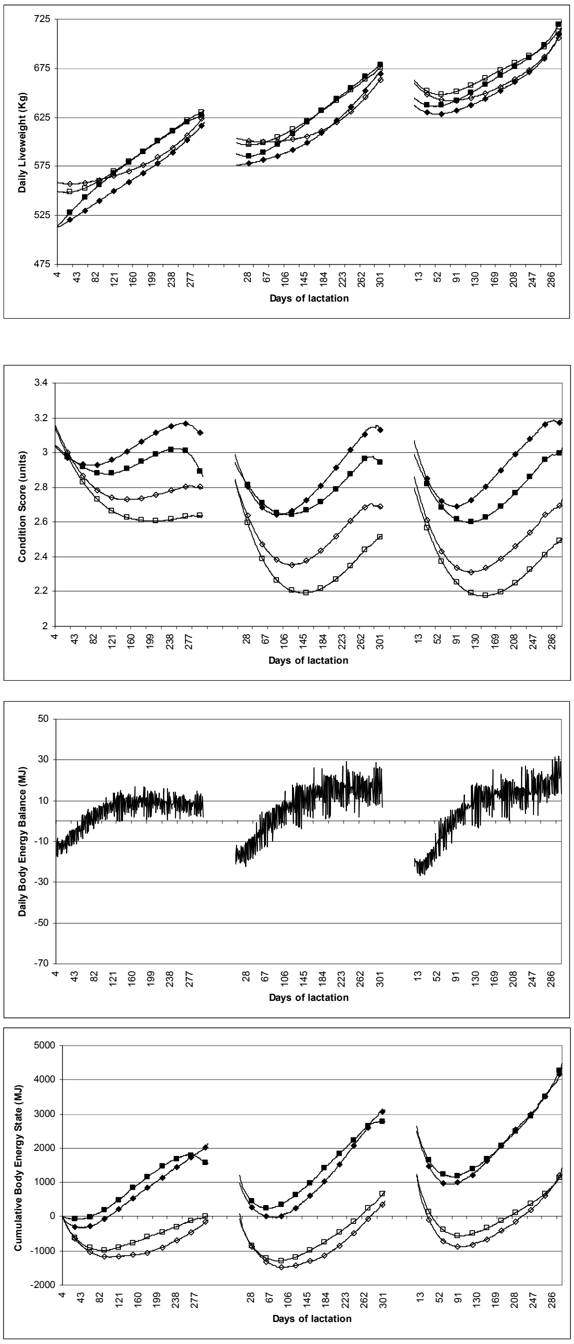

Figure 2a – 2d. Liveweight (kg) ,BCS (units), energy balance (MJ) and cumulative energy state (MJ) by day of lactation for three lactations for cows in groups low concentrate control (-■-), low concentrate select (-□-), high concentrate control (-◆-) and high concentrate select (-◇-).

There is an intimate relationship between body energy content, milk yield and profitability in dairy cows in part due to the cost of producing the body energy and in part due to the effect that changes in body energy have on traits such as health and fertility (Collard *et al.,* 2000; Gillund *et al.,* 2001). This suggests that body energy, or a parameter of its change, is a suitable candidate for inclusion in future selection indices. Incorporating body energy into an overall index would enable the selection of cows that have a suitable profile of body energy content at a given yield level. Selecting concurrently for yield and reduced body lipid loss in early lactation is, in effect, selecting for increased energy intake. This is predicted to improve health and welfare of cows but also has an economic cost. Veerkamp and Brotherstone (1997) suggest that a restricted index in which BCS is maintained at its (then) current level is predicted to reduce overall economic genetic gain by 5%. The most appropriate combination of yield and body lipid loss must be determined and an economic value calculated before it can be used in an overall profit index. This is worthy of future investigation.

Current genetic evaluations for production do not account for energy contributions from body tissue mobilisation, therefore some sires with high merit for production may have daughters with body tissue mobilisation profiles that predispose them to higher costs associated with poorer health and fertility. Deducting the body energy equivalent of kg milk from the breeding value for milk for each of 1240 progeny test sires resulted in a correlation of 0.98 between the ranking of sires before and after adjustment. However, some sires changed rank by large amounts, the largest being +355 positions (Coffey *et al.,* 2003).

Conclusions

Selection for yield alone has led to cows that mobilise more of their body energy in early lactation and cows that do not replenish all lost body lipid throughout their productive life. For select cows, this results in a net loss of body lipid that is greater when they are fed a low concentrate diet. These findings have implications for management systems required for cows selected for yield alone or for selection objectives for cows that must be kept in a low concentrate management environment. Future selection indices could include body lipid content in an attempt to limit BCS loss, NEB and the concomitant health and fertility problems. Integrated dairy management systems may provide more useful information in future, including automated BCS.

Acknowledgements

The authors would like to acknowledge the funding and long-term support of the Scottish Executive Environment & Rural Affairs Department. Defra are acknowledged for funding the work on automatic CS.

References

ARC. 1980. *The Nutrient Requirements of Ruminant Livestock*. Technical review by an agricultural research council working party. CAB International, Wallingford, UK.

Coffey, M.P., Emmans, G.E. & Brotherstone, S. 2001. Genetic evaluation of dairy bulls for energy balance traits using Random Regression. *Anim. Sci. 73,* 29-40.

Coffey, M.P., Simm, G., Hill, W.G. & Brotherstone, S. 2003. Genetic Evaluations of Dairy Bulls for Daughter Energy Balance Profiles Using Linear Type Scores and Body Condition Score Analysed Using Random Regression. *J. Dairy Sci. 86,* 2205-2212.

Collard, B.L., Boettcher, P.J., Dekkers, J.C.M., Peticlerc, D. & Schaeffer, L.R. 2000. Relationships Between Energy Balance and Health Traits of Dairy cattle in Early Lactation. *J. Dairy Sci. 83,* 2683-2690.

Dechow, C.D., Rogers, G.W. & Clay, J.S. 2002. Heritability and correlations among body condition score loss, body condition score, production and reproductive performance. *J. Dairy Sci. 85,* 3062-3070.

Fox, D.G., Van Amburgh, M.E. & Tylutki, T.P. 1999. Predicting requirements for growth, maturity and body reserves in dairy cattle. *J. Dairy Sci. 82,* 1968-1977.

Gillund, P., Reksen, O., Grohn, Y.T. & Karlberg, K. 2001. Body condition related to ketosis and reproductive performance in Norwegian dairy cows. *J. Dairy Sci. 84,* 1390-1396.

Veerkamp, R.F. & Brotherstone, S. 1997. Genetic correlations between linear type traits, food intake, liveweight and condition score in Holstein Friesian dairy cattle. *Anim. Sci. 64,* 385-392.

Wathes, D.C., Beever, D.E., Cheng, Z., Pushpakumara, P.G.A. & Taylor, V.J. 2002. Lifetime organisation and management of reproduction in the dairy cow. *British Society of Animal Science Occasional Publication 28,* 59-69.