Genetic and Economic Evaluation of Dairy Cow Body Condition Score in New Zealand

J.E. Pryce and B.L. Harris
Livestock Improvement Corporation Ltd,
Private Bag 3016, Hamilton, New Zealand

Abstract

Body condition score has been proposed as an additional trait in New Zealand's national breeding objective. For inclusion in the breeding objective, genetic parameters and an economic value are required. We propose genetic evaluation of body condition score using a random regression model that includes 3rd order Legendre polynomials fitted to genetic, cow PE and herd-test-day variances and a link function approach to account for heterogeneity of error variance over time. Multivariate analyses have shown that in New Zealand, body condition score is not genetically correlated with first lactation milk yield traits (when projected to a single common lactation length of 270 days). Moderate genetic correlations with fertility, survival, live weight and capacity were estimated. Four major areas have been identified as possible contributors to the economics of body condition score: energy status, lactation length, fertility and welfare.

Introduction

Although subjective, body condition score (BCS) is currently the only practical and inexpensive method of evaluating the body energy stores of large numbers of cattle.

The purpose of this paper is a summary of the progress that has been made in research to include body condition score as an additional trait in the New Zealand (NZ) national selection index, Breeding Worth (BW). The current version of BW includes breeding values for yields of milk, fat, protein plus liveweight, longevity and fertility weighted by their economic values; somatic cell count will be included shortly (Harris and Winkelman, 2004). It is anticipated that the next trait will be BCS, although this depends on its economic contribution to BW.

Materials and Methods

Data were collected on first lactation cows in herds that participated in either Livestock Improvement's or Ambreed's progeny-testing schemes, or participated in linear type classification from the 2000/01 through 2002/03 seasons. Two BCS measurements were taken in the progeny-test herds, when live weights were recorded and at the time of linear type classification. In the non-progeny-test herds, one BCS measurement was taken at the time of linear type classification. BCS was recorded visually on a 1 to 9 scale, where 1 is emaciated and 9 is obese. Additional data on first lactation records of 270-day milk, fat and protein yields; traits other than production (TOP; see Winkelman *et al.,* 2000) and cow fertility, breed and pedigree information were extracted from the Livestock Improvement national database. Breed proportions of the cow, dam and sire were available in 16ths which allowed both the calculation of breed, and heterosis effects (Koch *et al.,* 1985). The data set contained a total of 123,223 performance records.

Multivariate analysis

A multivariate analysis was undertaken with a single observation per cow for each trait. Where cows had two measurements recorded the first BCS measurement was used in the analysis. The model used included linear and quadratic terms for age; breed proportions of overseas Holstein-Friesian, NZ Holstein-Friesian and Jersey; heterosis effects and herd-year-season-day. Heritabilities, genetic and phenotypic correlations, and fixed effects were estimated by restricted maximum likelihood

(REML) with a multivariate linear sire model including a sire-maternal-grandsire relationship matrix using the average information algorithm of Johnson and Thompson (1995).

Longitudinal analysis

All of the BCS records on individual cows were used for these analyses. The fixed effect model was similar to that used in the multivariate analysis. A link function approach was used to account for heterogeneity of error variance over time (Jaffrezic *et al.,* 2000). herd-year-season-day was fitted as an additional random effect in models 2 to 4 inclusive (Gengler and Wiggans, 2001).

Model 1: Herd-test-day fitted as a fixed effect, sire and cow permanent environment (PE) as random effects.
Model 2: Herd-test-day, sire and PE as random effects.
Model 3: Sire, PE and herd-test-day were modelled as a continuous function of time using 2^{nd} order Legendre polynominals.
Model 4: As model 3, except that sire, PE and herd-test-day were modelled as a continuous function of time using 3^{rd} order Legendre polynominals.

Different combinations of orders of Legendre polynomials were tested and there was found to be no advantage in fitting mixed order models. Convergence problems were experienced when the order of Legendre polynomials was increased above 3.

The sire, herd-test-day and cow PE variances and the fixed effects were estimated with a linear sire model including a sire-maternal-grandsire relationship matrix using ASREML software Gilmour *et al.* (2001). Goodness-of-fit was calculated using Schwartz's Bayesian Information Criterion (BIC).

Results

Multivariate analysis

The heritability estimate of BCS was 0.20 (0.01). The genetic correlation estimates between BCS and milk, fat and protein yields were not significantly different from zero (Table 1). The milk production data were adjusted to 270-day yields, therefore effects of BCS on lactation length will not be shown. Genetic correlations with actual yield may have given different results.

Genetic correlations with fertility traits and survival were positive and of moderate size. BCS is moderately correlated with live weight and capacity, but not stature.

Table 1. Genetic and phenotypic correlations (rg and rp) between BCS and milk production, live weight, stature, capacity, cow fertility and survival from 1^{st} to 2^{nd} lactation.

	rg (se)	**rp**
270 d fat yield	0.03 (0.04)	-0.01
270 d protein yield	-0.01 (0.04)	-0.006
270 d milk yield	-0.07 (0.04)	0.11
Live weight	0.24 (0.04)	0.21
Stature	0.05 (0.04)	0.11
Capacity	0.62 (0.03)	0.32
Calf born to AI	0.35 (0.02)	0.07
PM21*	0.48 (0.05)	0.10
Survival	0.38 (0.07)	0.06

*Presented for mating in the first 21 days from start of mating

Longitudinal analysis

Including herd-test-day as a random effect improved the fit of the model (Table 2). BIC were smaller (better fit) when herd-test-day was fitted as a random effect. The model fit also improved as the order of Legendre polynomial was increased, although the improvement when the order was increased from 2 to 3 was small.

Table 2. Summary of random regression models which provide the best fit of data based on BIC.

Model	-2*loglik	DF	BIC
1	-82741	120333	-309473
2	-87912	123210	-347605
3	-87966	123210	-367783
4	-88270	123210	-368864

Heritabilities estimated using the random regression model were between 0.15 and 0.25.

Discussion

Genetics

Random regression is the method of choice for estimating breeding values when multiple measurements on individual animals are available. An additional benefit is the flexibility in choice of expression of breeding values e.g. relevant to the aspect of BCS under consideration.

Genetic correlations between BCS and fertility measures were moderate in the multivariate analyses, suggesting that BCS may be a useful selection criterion for fertility. The genetic correlation between BCS and 270-day milk yield was close to zero, indicating that selection for volume will have little effect on BCS. This contradicts most recent studies from outside New Zealand, where the genetic correlation between BCS and yield traits are significantly different from zero. For example Veerkamp *et al.* (2001) estimated it to be –0.31. This could be because in New Zealand little or no emphasis has been placed on angularity or dairyness in national breeding objectives, whereas in many other countries there has been some selection for both milk yield and angularity in tandem. Angularity and BCS are genetically related traits in the linear type evaluation systems operated in most countries.

Progress in calculating the economic value

Calculating the economic value of BCS is work in progress. So far, we have identified four main areas that we believe contribute to the economic value.

Energy balance

To estimate the contribution of BCS energy is modelled longitudinally through lactation. Changes in body lipid and protein content can be directly linked to changes in BCS (e.g. Gregory *et al.,* 1998). Energy is required for production, maintenance, activity, pregnancy and growth and is obtained from either intake or body tissue mobilisation. The energy prediction equations for milk production, maintenance, activity and pregnancy used in the New Zealand Animal Evaluation farm model are based on the equations published by AFRC (AFRC, 1993) with some adaptations (e.g. extra activity costs to account for cows being at pasture)

In order to calculate energy from body condition score change, energy required for growth has to be distinguished from energy for body condition score gain. Growth has been defined as the change in liveweight from the start to the end of lactation minus the live weight that can be attributed to body lipid. Daily growth is then calculated as growth per day when liveweight change is positive. Gain of BCS was assumed to be due to changes in body lipid. Loss of BCS was assumed to be due to a reduction in body lipid and protein. Proportion of body fat can be calculated from BCS for NZ cows (Gregory *et al.,* 1998). Calculating the effect of BCS change is based on the principles used by National Research Council (2001), assuming that fat is approximately 39MJ/kg and protein 23.2 MJ/kg (National Research Council, 2001).

Lactation length

In New Zealand dairy farming systems, BCS is frequently a major decision rule for drying off. Cows in low body condition are often dried off earlier in the season in order to be in suitable body condition to start the next lactation. The benefits of extra days in milk (due to higher BCS) at the end of lactation can be calculated from a lactation curve. In the analysis presented in this paper, it is worth noting, that if milk yield was not adjusted to 270-days of lactation-length, the relationship between milk yield and BCS may have been quite different to the results we have shown.

Welfare

Although often considered as a “difficult to include” aspect in derivation of economic values, animal welfare is an important aspect of the economics of BCS. Gregory *et al.* (1998) looked at the relationship between BCS and physically dissected body composition using 40 cull Friesian and Friesian cross cows in New Zealand. They found a quadratic relationship between BCS and estimated total body fat, with no change in basal body fatness when BCS was three or less. It is possible that strain differences exist (e.g. some strains or breeds having different basal levels of fatness).

Fertility

To demonstrate the potential power of using BCS as a proxy for fertility, a simple calculation of correlated responses shows that selection on BCS is 0.96 times as efficient as selecting directly on the NZ fertility breeding value. Issues to do with double counting that will need to be resolved, as fertility is already included in the Breeding Worth index.

Conclusions

Breeding values for BCS will be estimated using a random regression model. The economic emphasis on BCS in the New Zealand selection index (BW) will ultimately depend on the combined importance of those areas that we identify as contributing.

Acknowledgements

We are grateful to Bill Montgomerie from Animal Evaluation Unit for his contribution to this paper.

References

AFRC 1993. *Energy and protein requirements of ruminants.* An advisory manual prepared by the AFRC Technical Committee on Responses in Nutrients. CAB International. Wallingford, UK.

Gengler, N. & Wiggans, G. 2001. Heterogeneity in (co)variance structures of test-day yields. *Interbull Bulletin 27,* 179-184.

Gilmour, A.R., Cullis, B.R., Welham, S.J. & Thompson, R. 2001. *ASREML Reference Manual.* NSW Agriculture, Orange, Australia.

Gregory, N.G., Robins, J.K., Thomas, D.G. & Purchas, R.W. 1998. Relationship between body condition score and body composition in dairy cows. *New Zealand Journal of Agric. Research 41,* 527-532.

Harris, B.L. 2002. Genetics of body condition score in New Zealand dairy cattle. *Proceedings of the 7th World Congress on Genetics Applied to Livestock Production. CD-ROM communication n° 01-03.*

Harris, B.L. & Winkelman, A.M. 2004. Testday model for national genetic evaluation of somatic cell count in New Zealand. *Interbull Bulletin 32,* 103-106

Holmes, C.W., Brookes, I.M., Garrick, D.J., MacKenzie, D.D.S., Parkinson, T.J. & Wilson, G.F. 2002. *Milk Production from Pasture.* 2nd Edition. Palmerston North, Massey University.

Jaffrezic, F., White, J.M.S., Thompson, R. & Hill, W.G. 2000. A link function approach to model heterogeneity of variance over time in lactation curve analysis. *J. DairySci. 84,*1255-1264.

Johnson, D.L. & Thompson, R. 1995. Restricted maximum likelihood estimation of variance components for univariate animal models using sparse matrix techniques and average information. *J. Dairy Sci. 84,* 1255-1264.

Koch, R.M., Dickerson, G.E., Cundiff, L.V. & Gregory, K.E. 1985. Heterosis retained in advanced generations of crosses among Angus and Hereford cattle. *J. Anim. Sci. 60*, 1117-1132.

National Research Council 2001. *Nutrient requirements of dairy cattle.* 7th Revised Edition. National Academy Press.

Veerkamp, R.F., Koenen, E.P.C. & de Jong, G. 2001. Genetic correlations among body condition score, yield and fertility in first parity cows estimated by random regression models. *J. Dairy Sci. 84,* 2327-2335.

Winkleman, A.M., Harris, B.L. & Montgomerie, W.A. 2000. Analysis of management traits in New Zealand dairy cow population. *Interbull Bulletin 25,* 139-142.