First Results of Body Condition Score Modeling for Walloon Holstein Cows

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Introduction

Body Condition Score (**BCS**) provides some information about the stored energy reserves of dairy cows and is linked to production, fertility and health traits. If BCS is regularly recorded in a herd, producers can fine-tune feeding and management practices. Body condition scoring can thus be a valuable management tool. Also selection for improved or more stable BCS is considered beneficial for cow robustness.

Since April 2006, BCS is monthly recorded in 76 dairy herds of the Walloon Region of Belgium. The first objective of this recording is to develop and offer later practical management tools to dairy farmers. Therefore, BCS results are sent to each breeder as a “Herd BCS Balance Sheet”. It allows him to point, across time, the groups of cows which are not in the range of desirable scores according to their parity or lactation stages. The second objective of the Walloon BCS recording is to model data in order to estimate breeding values for this trait. However, BCS is not yet routinely recorded in the Walloon Region and data have been collected only for one year. Nevertheless, linear type traits are largely available for many herds since 1992. Especially angularity, also called dairy form, tends to describe the same features of the dairy cow as the BCS.

The aim of this research was to study the potentialities of using a two-trait random regression animal model for first lactation BCS and angularity in order to estimate BCS breeding values.

Materials and Methods

Data

Since April 2006, BCS is monthly collected by milk recording agents, in 76 dairy herds of the Walloon Region. Dairy cows are given a BCS based on a nine-point scale (with unit increments) similar to recommendations by ICAR (2007). The main descriptors at each BCS class were adapted from the principal descriptors of specific body regions of the five-point scale described by Ferguson *et al.* (1994). The decision chart followed by the BCS recorders is given in Table 1. It is mainly based on the observation of the thurl region, the pin and hip bones and the sacral and coccygeal ligaments, with scoring of 1 (= emaciated cow) to 9 (= obese cow).

Table 1. Decision chart for body condition scoring in the Walloon Region.

Principal descriptors of body region	BCS
The thurl (rump region) has a V appearance.	<= 5
Hook bone is rounded.	5
Hook and pin bones are angular. Pin bone has a palpable fat pad.	4
Pin bone does not have a palpable fat pad. The transverse processes of the lumbar vertebrae are sharp.	3
Thurl is prominent and the cow has a saw-toothed spine.	2
Severely emaciated. All skeletal structures are visible.	1
The thurl (rump region) has a U appearance	> 5
The sacral ligament is visible and the coccygeal ligament is faintly visible.	6
Both sacral and coccygeal ligaments are not visible.	7
The thurl region flattens and becomes round. Pin bone is round.	8
All osseous protuberances are round.	9

Angularity describes the dairy character of the cow based on the angle and the openness of the ribs as well as the flatness of bones and the form of the shoulder. It is recorded on a scale of 1 (lacks angularity close ribs coarse bone) to 9 (very angular open ribbed flat bone) with unit increments (ICAR, 2007).

Only data from first lactation Holstein cows were used in this study. Records from days in milk (**DIM**) >365 were eliminated. The final data set contained 68,552 angularity records from 67,867 cows in 1,311 herds and 23,293 BCS records from 2,132 cows in 76 herds. 685 cows were classified twice during the first lactation and 1,070 cows had both angularity and BCS records. Pedigree data were extracted from the database used for the official Walloon genetic evaluations. Animals born before 1985 were eliminated, no unknown parents groups were defined and redundant animals were removed. The final pedigree file included 143,556 animals.

(Co)variance Estimation and Models Used

In order to estimate (co)variance components, 34,174 records from 24,504 cows in 251 herds were extracted from the original data set. Herds were required to have at least one cow with two angularity records or one cow with BCS records, in first lactation. Pedigree data represented 76,301 animals.

First of all, genetic parameters were estimated by REML using two separate single-trait random regression models, respectively for angularity and BCS. After that, a two-trait model was developed for the final (co)variances estimation using REML and for breeding values estimation:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Hh} + \mathbf{Q}(\mathbf{Wc} + \mathbf{Zp} + \mathbf{Za}) + \mathbf{e}$$

where:

- **y** is the vector of BCS and angularity records,
- **b** is the vector of the fixed effect of class of 14 DIM*age at calving group,
- **h** is the vector of the fixed herd*test-day effect for BCS and herd*date scored* classifier*classification system effect for angularity (there was a succession of different classification systems between 1992 and 2007 in the Walloon Region),
- **c** is the vector of BCS recorder random regression coefficients for BCS or the vector of classifier*classification system random regression coefficients for angularity,
- **p** is the vector of permanent environmental random regression coefficients,
- **a** is the vector of additive genetic random regression coefficients,
- **e** is a vector of random residuals,
- **X, H, W, Z** are incidence matrices,
- **Q** is the covariate matrix of second-order Legendre polynomials.

Five age at calving groups were defined as <26, 26 to 27, 28 to 29, 30 to 32 and >32 months. Residual effects were assumed to be uncorrelated across traits.

Heritabilities for the entire lactation, daily heritabilities and averaged daily heritabilities were computed as the ratio of genetic variance to total variance. Genetic correlations were also estimated based on (co)variances matrix.

Breeding Values Estimation

For breeding values computation, the model used for parameters estimation was applied on the total data set and solved by sparse inversion. Firstly, BCS breeding values were calculated with complete (co)variance matrices. Secondly, BCS breeding values were computed without taking into account relationships between BCS and angularity using a univariate system applied to BCS data using the same (co)variance components.

These two sets of breeding values were compared based on their reliability (**REL**) defined as the squared correlation between true and predicted breeding values. It was estimated based on the diagonal elements of the mixed model equations, as shown by Henderson (1984). Prediction Error Variance (**PEV**) given by direct inversion of the coefficient matrix allowed the estimation of correct reliabilities:

$$\mathrm{REL} = \frac{\sigma_{\mathrm{a}}^2 - \mathrm{PEV}}{\sigma_{\mathrm{a}}^2}$$

where σ_a^2 is the additive genetic variance.

Results and Discussion

Phenotypic data

Phenotypic means for BCS and angularity were 5.07 ± 0.96 and 5.73 ± 1.07, respectively. Figure 1 represents the evolution of phenotypic means for each DIM classes covering each 14 days. Average BCS at calving was about 5.30 and average BCS loss was around 0.6 near 60 DIM. The curve for angularity seemed to be a mirror image of the curve for BCS, but was flatter. It decreased more slightly at the end of the lactation, compared to the BCS curve which rose steadily. Average angularity gain was around 0.4 near 60 DIM.

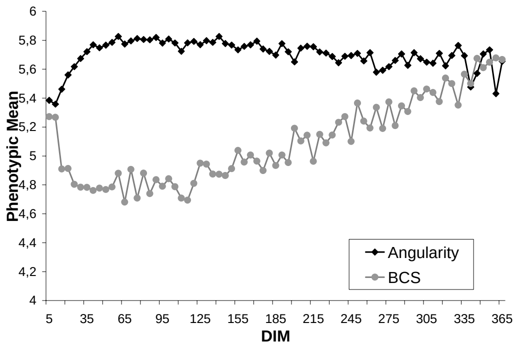

Figure 1. Phenotypic means for BCS and angularity within classes of 14 DIM for first lactation.

(Co)variances Estimation

Variance components and heritabilities across lactation are shown in Table 2. The classifier *system variance is lower for angularity than the recorder variance for BCS (respectively 29% and 16% of the total variance). These results indicate a higher variability among BCS recorders than among classifiers. While classification has been implemented in the Walloon Region since 1992, body condition scoring has been introduced only one year ago and it was done by milk recorders who were unfamiliar with body type. Lactation heritability estimate for BCS was lower than for angularity, respectively 0.22 and 0.31.

Table 2. Variances and heritabilities estimates for BCS and angularity for the first lactation.

	BCS	Angularity
Residual variance	0.31	0.34
Recorder variance for BCS or classifier*system variance for angularity	0.23	0.05
Permanent environmental variance	0.15	0.34
Additive genetic variance	0.11	0.17
Lactation heritability	0.22	0.31

Daily heritability for BCS did not differ significantly along the lactation. The range of estimates was from 0.13 to 0.15 (Figure 2). It was lower than in other previous studies using an animal model: from 0.27 to 0.51 (Koenen *et al.*, 2001; Berry *et al.*, 2003; Gallo *et al.*, 2001). This difference may be due to the data structure (only first lactations were used) or to the model (e.g. these studies did not include a random effect for BCS recorder, some used a sire model). Average of daily heritability for BCS was 0.14.

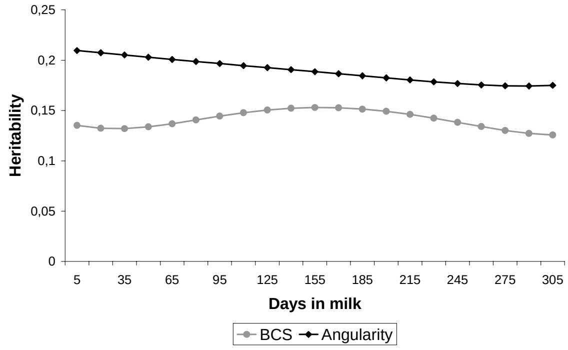

Figure 2. Heritability for BCS and angularity across time for the first lactation.

Daily heritability for angularity was 0.19 (Figure 2) and was lower than the one used in genetic evaluation (0.28). Differences in the model and in data used for variances components estimation could explain this deviation.

Correlations

Genetic and phenotypic correlations between BCS and angularity were negative (Figure 3). While Figure 1 indicated similar but inverse curves for both traits, average phenotypic correlation looked moderate (-0.24) and genetic correlation was -0.54 (Figure 3). Genetic correlation for first lactation cows was reported to range from -0.35 to -0.73 (Veerkamp and Brotherstone, 1997; Dechow *et al.*, 2003; Kadarmideen and Wegmann, 2003; Lassen *et al.*, 2003). However, these values were estimated based on different data sets (e.g., change in BCS scale, BCS treated as a longitudinal data or not) or with different type of models (e.g., animal or sire, fixed effects).

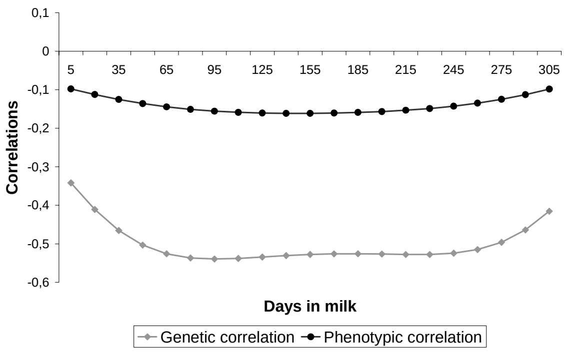

Figure 3. Genetic and phenotypic correlations between BCS and angularity within DIM for the first lactation.

Cows with low BCS tended to be angular and thin. However, BCS and angularity are not exactly the same trait. Moreover, they are not equally influenced by environmental parameters. For example, BCS recorders tried to describe the energy status for a given cow for a specific test-day while classifiers tend to correct the angularity score for the lactation stage.

Breeding Values Estimation

Breeding values and reliabilities estimation was done on 3 data subsets: animals of the entire pedigree file (Set 1), cows with BCS and/or angularity records (Set 2) and finally sires with at least 10 daughters in 10 herds under milk recording (Set 3). Breeding values and reliabilities reported in the following tables correspond to the first Legendre coefficient.

Average REL (**M_{REL}**) and standard deviation of REL (**SD_{REL}**) computed for the three data sets both with univariate and bivariate models are shown in Table 3. Using the bivariate system for BCS, **M_{REL}** of the three data sets were multiplied by two. In our situation, angularity information provided additional correlated information and data depth in time. The abundance of angularity data filled in quiet successfully the lack of data for BCS, while genetic correlation between these 2 traits was only moderate.

Table 3. Number of observations (N), average reliabilities (M_{REL}) and standard deviation (SD_{REL}) computed for the three data sets both with univariate and bivariate models

	N	$M_{REL} \pm SD_{REL}$	
		Bivariate	Univariate
Set 1	143,556	0.114 ± 0.071	0.058 ± 0.068
Set 2	69,133	0.151 ± 0.060	0.079 ± 0.073
Set 3	1,848	0.176 ± 0.147	0.090 ± 0.126

Table 4 represents the number of sires in each class of REL. For example, adding angularity information increased the number of sires reaching a given threshold for publication of breeding values. For a threshold of 0.45, the number of potential publishable sires doubled and increased from 49 to 98.

Table 4. Number of sires in Set 3 in each class of reliability (with univariate and bivariate models)

Reliability	Bivariate	Univariate
0.00 to 0.05	490	986
0.06 to 0.15	364	460
0.16 to 0.25	487	223
0.26 to 0.35	304	82
0.36 to 0.45	105	48
0.46 to 0.55	59	22
0.56 to 0.65	20	18
0.66 to 0.75	15	5
0.76 to 0.99	4	4

Breeding values estimated for BCS with the bivariate model for sires with a REL over 0.25 ranged from -0.73 to 0.49 BCS units with an average of -0.03 and a SD of 0.11.

Conclusions and Perspectives

This study showed moderate lactation heritability for BCS (0.22) as well as moderate genetic correlation among BCS and angularity (-0.52). But our research demonstrated the interest of using correlated traits in order to estimate sire breeding values and improve their reliabilities. Future research will investigate others traits, e.g. strength which has shown in other studies a genetic correlation with BCS of 0.72 in first lactation cow (Dechow *et al.*, 2003).

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