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Abstract

Body condition score (BCS) is a good estimate of body reserves and could serve as a proxy to prevent some metabolic disorders. Based on 686 lactations from three experimental farms, we investigated to what extent BCS direct genomic values (DGV) from the national evaluation, estimated independently from the phenotypes of this study, reflect profiles of body reserves along lactation, and how it affects body weight, feed intake and milk production. A model including different regressions of BCS DGVs was applied to each trait over the lactation period. Differences in BCS DGV resulted in differences in observed BCS and body weight during the entire lactation. Differences in daily milk production reached 1kg per day all along lactation. Interestingly, feed intake increased more rapidly with BCS DGV in early lactation but was similar thereafter. The BCS index is a promising tool to limit intense mobilization in early lactation but still needs further investigation.

Introduction

Body reserves are used as an adjustment variable for feed intake during the lactation period. In early lactation, the increase in feed intake is indeed not sufficient to cover the energy requirements for milk production (Banos et al., 2005) and cows therefore enter a negative energy status that leads them to mobilize their body reserves (Friggens et al., 2004). Conversely, later in the lactation, when milk production decreases while intake is still high, cows can recover and build new body reserves. Body condition score (BCS) is a good estimate of the amount of stored fat on the body (Broster and Broster, 1998), despite being based on the human eye which makes it difficult to identify small changes on a short time interval. It has been shown that positive genetic correlations exist between BCS and feed efficiency components such as feed intake and body weight (Manzanilla-Pech et al., 2016). However, if cows with high genetic merit for milk production are reported to mobilize more body reserves than cows with lower genetic merit (Pryce et al., 2001), a too intense mobilization is not favourable as it can lead to metabolic disorders (Weber et al., 2013) and poor fertility. In France, estimated breeding values (EBV) are calculated based on one measure of BCS recorded during the first lactation. In this article, we investigate to what extent this genomic evaluation based on a single phenotypic record per cow may reflect different dynamics of body reserves along the lactation period and how it could be used to limit mobilization in early lactation. We also investigated how differences in BCS evaluation would affect levels and trajectories of other traits such as feed intake or milk production.

Materials & Methods

Population resources and feeding management. This experiment was carried out from 2014 to 2020 using Holstein cows from three French experimental farms: 169 Holstein cows from the Le-Pin-Au-Haras INRAE facility, 145 from the Mejusseaume INRAE facility and 121 from the Trinottières experimental farm, representing a total of 686 lactations with parity ranging from 1 to 7. All animals were handled with care in accordance with the French Ministry of Agriculture guidelines for animal research and the applicable European Union guidelines and regulations on animal experiments. Cows were fed individually using an electronic gate feeding system and ear-tag identification. A total mixed ration (TMR) was distributed *ad libitum* (approximately 10% left overs). For Mejusseaume, the TMR was based on maize silage and concentrates with an energy value of 0.93 forage unit by kg of dry matter (UFL/kg of DM, 1 UFL equating to 7.12 MJ of net energy for lactation, INRA, 2018). In Trinottières, two TMR were used (one half of the cows for each diet): one based on maize silage and concentrates and the other one including grass silage, with an energy value of 0.96 and 1.00 UFL/kg of DM respectively. Finally, in Le Pin, the TMR was based on maize silage, with grass silage, rapeseed meal, minerals and concentrates, and an energy value of 0.95 UFL/kg of DM.

Phenotyping and trait definition. Cows were milked twice daily and milk yield (MY) was individually recorded at each milking. Body weight (BW) was recorded at each milking using an automatic weighing system. Individual daily feed intake was measured as the difference between distributed and next morning refusals weight (Mejusseaume and Trinottières) or as the sum of intake weighed at each visit of the cow (Le Pin). Dry matter intake (DMI) was calculated daily, based on dry matter content of TMR. Body condition was scored on a 5-point scale with 0.25 steps by the same 2 or 3 trained scorers, monthly or every 2 weeks, depending on the farm. Average BCS of the scorers was used. The study included data from 5-250 days in milk (DIM).

Genotyping and genomic evaluation. All animals were genotyped with the Illumina SNP50k or EuroG10k chip (Illumina Inc., San Diego, CA) from blood samples or ear punches. Genotyping was performed at LABOGENA, Jouy-en-Josas, France. Missing 50k genotypes were imputed with FImpute (Sargolzaei et al, 2014). Direct genomic values (DGV) of experimental animals were obtained by combining their genotypes with the SNP effects estimated by the French national evaluation system. It is worth noting that phenotypes from these three experimental farms are not used in the national evaluation and therefore DGVs used in this study were fully independent of any phenotypic information from the animals. BCS index was expressed in genetic standard deviations, with a zero mean.

Statistical analysis. For each of the four considered traits (MY, DMI, BW and BCS), effect of BCS index (iBC) on trait trajectory over lactation was analysed with a model including: (i) a lactation curve to take DIM into account, and (ii) different regressions on BCS index in order to estimate its impact on the trait.
At each day in milk, the following model was applied:

$$y_{it} = \mu + x_i*f + WIL_t(parity) + reg_{it}(BC) + \varepsilon_i \quad [1]$$

$$WIL_t(parity) = a + b*t + c*e^{-0.06*t} \quad [2]$$

$$reg_{it}(BC) = \alpha*iBC + \beta*iBC*st + \gamma*iBC*st^2 \quad [3]$$

where y_{it} is the performance of animal i at DIM t, μ is the overall mean, f is the vector of fixed effects of farm-date and, for MY and BW, the corresponding DGV as a covariate, x_i is the incidence vector relating cow i to fixed effects, $WIL_t(parity)$ is the intra parity Wilmink model of the lactation curve (primiparous *vs*. multiparous) as described in equation [2] (Wilmink, 1987) and $reg_{it}(BC)$ is the regression on BCS index as described in equation [3] with st the standardized DIM ((t-125)/250) and ε_i is the residual.
Analyses were performed with the GLM procedure of the SAS software (SAS institute Inc., 2008).

To illustrate BCS DGV effects, results were averaged by class of DGV values. Five classes were defined as follows: "BC--" if iBC ≤ -1; "BC-" if -1 < iBC ≤ -0.5; "BC0" if -0.5 < iBC < 0.5; "BC+" if 0.5 ≤ iBC < 1; "BC++" if iBC ≥ 1. BC classes included 29, 69, 184, 90 and 63 cows, respectively.

Results

The descriptive statistics regarding MY, DMI, BW and BCS for overall lactations showed no differences in mean DMI, BW and MY between farms. Some slight differences in BCS existed between farms with the highest value for the Trinottières farm (2.7 points), an intermediate value for the Le Pin farm (2.3 points) and the lowest value for the Mejusseaume farm (2.0 points). Trajectories of MY, DMI, BW and BCS are presented in Figure 1. Daily milk rapidly increased by 12 kg between 5 and 50 DIM, then slowly decreased. On the contrary, DMI increased by 8 kg between 5 and 50 DIM but much more slowly than milk. BW decreased by 14 kg during the first two weeks of lactation, and then increased constantly with animals gaining on average 80 kg in total. Regarding BCS, the tendency curve shows a small condition loss of 0.25 points at the beginning of lactation, then a recovery of 0.4 points at the end of lactation.

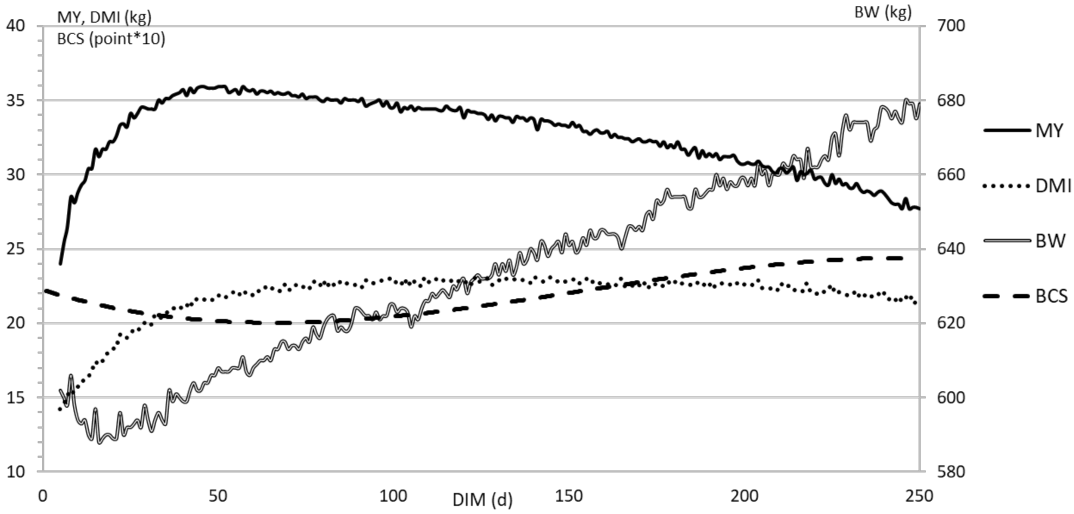

Figure 1. Trajectories of milk yield (MY), dry matter intake (DMI), body condition score *10 (BCS) and body weight (BW) over days in milk (DIM).

The effects of BCS index on trait trajectories are presented in Figure 2. Regarding BCS (figure 2a), positive BC cows always had a greater score than negative BC cows, independent of the stage of lactation. This difference increased along the first 6 months with a 0.4 and 0.8 score difference between extremes in the beginning and mid lactation, respectively. Negative BC cows had a greater milk production (Figure 2b) with barely no difference between extremes at the beginning of lactation, and 1.2 kg per day difference in the middle of lactation. Regarding DMI (Figure 2c), positive BC cows had a greater intake at the beginning of lactation (+1.2 kg a day). After 100 days, we observed no more difference between cows. Negative BC cows were lighter than positive BC cows (Figure 2d) with an increasing difference over lactation from 40 to 65 kg.

Discussion

The small difference observed in the average BCS among the farms is more likely due to slight differences of scale interpretation among the technicians rather than real differences of body reserves, as there was no cross-validation of scores nor common training of technicians. However, these differences were accounted for in the fixed effects of the models.

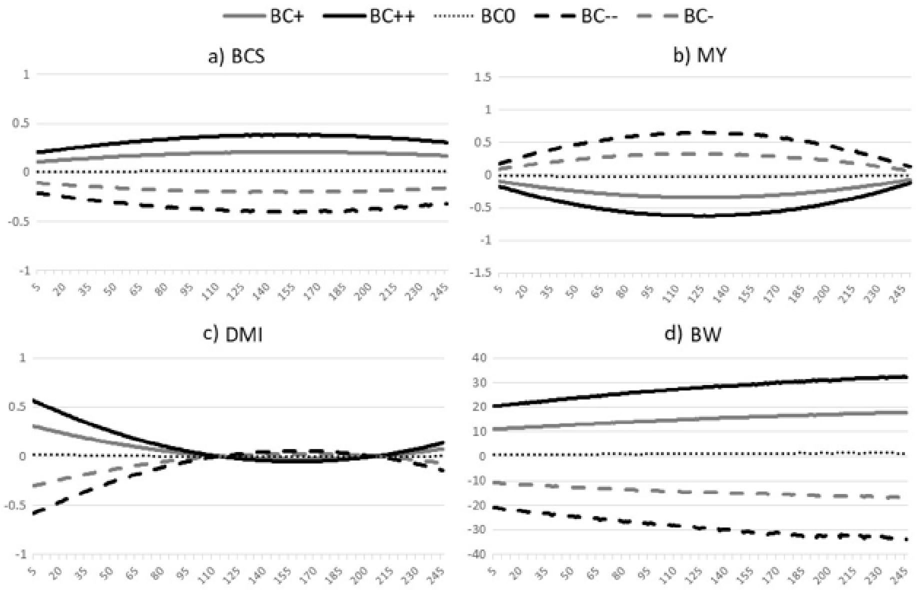

Figure 2. Effect of Body Condition Score (BCS) index on trajectories of a) BCS (points), b) milk yield (MY, kg), c) dry matter intake (DMI, kg) and d) body weight (BW, kg) from 5 to 250 days in milk.

Observed differences in BCS were in agreement with BCS DGV but a bit lower at the beginning of the lactation. These differences in BCS DGV also translated into moderate differences of BW increasing all along the lactation. Changes of MY per day are minimal (1L maximum per day between extreme groups) but cumulative. DMI is influenced only in early lactation. Therefore, the BCS index is a promising tool to limit intense mobilization in early lactation but still needs further investigation.

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