Relationship Of Energy Balance And Fat Protein Ratio Of Milk To Disease Liability In Dairy Cattle

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Introduction

A steady increase of milk yield has intensified the *post partum* energy deficit in dairy cattle (Veerkamp and Koenen (1999)). Cows in an extreme state of negative energy balance (EB) during early lactation show higher incidences of diseases such as mastitis, lameness, and metabolic disorders like ketosis (Goff and Horst (1997); Collard *et al.* (2000); Ingvartsen *et al.* (2003)). The fat protein ratio of milk (FPR) could serve as a low-cost measure of the EB status (Grieve *et al.* (1986)) and might be used as a selection criterion to improve overall health. Although several significant phenotypic associations between health and EB traits were reported in literature, little is known about their genetic relationship. Therefore, genetic parameters among EB, FPR, mastitis, claw and leg diseases, and metabolic disorders were estimated.

Material and methods

1,589 Holstein Friesian heifers were studied during the first 180 lactation days at the dairy research farm Karkendamm. Number of sires was 349, with 4.5 daughters on average. Disease information was recorded between January 2000 and February 2010. Three disease categories were analyzed: mastitis, claw and leg diseases, and metabolic disorders. Disease codes were generated in an analogous manner for all categories. Each observation (day) was allocated a code, “1” if the cow showed a disease and “0” otherwise. In case of a recorded udder treatment, the day of treatment and the following 5 days in milk were coded with “1”. An 8-day period was considered for the other traits. Using a Bayesian approach, variance components for diseases were estimated with the Gibbs sampling algorithm implemented in the LMMG_TH program, a threshold model modification of LMMG (Reinsch (1996)). For each trait, 120,000 iterations were generated and the results of each iteration retained. Convergence was determined by visual inspection. The results of the first 20,000 iterations were discarded as burn-in. The following animal threshold model was applied:

$E\,[\pi_{ijklm}] = \Phi\,(AFC_i + LW_j + YS_k + p_l + a_m)$,

with $E\,[\pi_{ijklm}]$ = expected probability for occurrence of the specific disease, Φ = cumulative probability function of standard normal distribution, AFC_i = fixed effect of i-th age at first calving (i = 1 to 3), LW_j = fixed effect of j-th lactation week (j = 1 to 9 for metabolic disorders, j = 1 to 26 for mastitis and claw and leg diseases), YS_k = fixed effect of the k-th year-season (k = 1 to 34), p_l = random permanent environmental effect of the l-th animal (l =

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1 to 1,582 for metabolic disorders, l = 1 to 1,589 for mastitis and claw and leg diseases), a_m = random additive genetic effect of the m-th animal (m = 1 to 4,293). Breeding values were multiplied by (-1) so that heifers with a low liability to diseases received higher breeding values.

Individual feed intake, milk yield and live weight per day were recorded automatically for lactation day 11 to 180 between September 2005 and April 2009. EB was calculated as the difference between energy intake and estimated energy requirements for milk output and maintenance as a function of live weight. Weekly FPR measurements were available. EB and FPR data were analyzed using the following random regression model:

$$y_{ijklm} = TD_i + AFC_j + \sum_{n=1}^{4} b_n x_{ijklmn}(d) + \sum_{n=0}^{2} p_{kn} x_{ijklmn}(d) + \sum_{n=0}^{2} a_{ln} x_{ijklmn}(d) + e_{ijklm},$$

with y_{ijklm} = observation of EB or FPR, TD_i = fixed effect of test day (i = 1 to 942 for EB, i = 1 to 186 for FPR), AFC_j = fixed effect of age at first calving (j = 1 to 5), b_n = fixed regression coefficients on lactation day d with $x_{ijklm1}(d) = d/190$, $x_{ijklm2}(d) = (d/190)^2$, $x_{ijklm3}(d) = \ln(190/d)$ and $x_{ijklm4}(d) = (\ln(190/d))^2$, p_k = random regression coefficients for the permanent environmental effect of animal k and a_l = random regression coefficients for the additive genetic effect of the l-th animal with $x_{ijklm0}(d) = 1$, $x_{ijklm1}(d) = -1+2(d-11/d_{max}-11)$ and $x_{ijklm2}(d) = 0.5(3(-1+2(d-11/d_{max}-11))^2-1)$ (k = 1 to 526 for EB, k = 1 to 627 for FPR, l = 1 to 4,293), and e_{ijklm} = random error. Variance components were estimated univariately and bivariately by REML, respectively, using the software package VCE-6 (Kovač and Groeneveld (2007)). The results provided the basis for the estimation of breeding values with ASReml-3 (Gilmore *et al.* (2009)). Breeding values for FPR were multiplied by (-1), because a low FPR is considered to be preferable.

Results and discussion

Mastitis incidence showed a strong peak at the beginning of lactation. Metabolic disorders clearly accumulated in early lactation, whereas claw and leg diseases were observed during the whole recording period (see Figure 1).

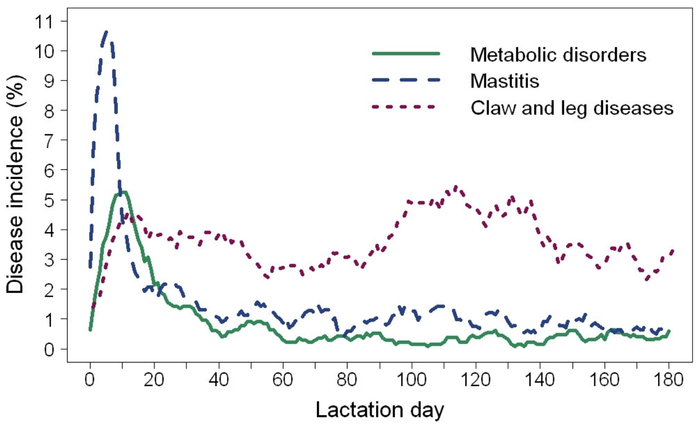

Figure 1: Frequencies of diseases during the first 180 days in milk

The higher incidence of diseases in the initial lactation period is in agreement with findings from literature (*e.g.* Drackley (1999)). Table 1 shows heritability estimates for health traits and the percentage of test-days cows were affected.

Table 1: Recording periods, number of observations, frequencies and heritabilities of disease traits

Trait	Lactation period (d)	Cow days total	Cow days affected (%)	h^2 (SE)
Mastitis liability	0 to 180	248,283	1.6	0.10 (0.05)
Claw and leg diseases	0 to 180	248,283	3.6	0.12 (0.03)
Metabolic disorders	0 to 62	92,563	6.2	0.07 (0.04)

Heritability of EB was low (h^2 = 0.03 to 0.14), which coincides with Berry *et al.* (2009). The genetic determination of EB was most pronounced at the onset of lactation and in early mid lactation. Heritability of FPR ranged from 0.14 to 0.49 with the highest values found at the beginning of lactation and at the end of the data recording period. On average, heifers exhibited a negative EB during the first 42 days in milk. FPR appeared to be a well suited EB indicator during the critical early stage of lactation; genetic correlations between both traits were -0.55 and decreased to -0.15 in later lactation. Genetic correlations between daily EB across lactation stages ranged between -0.73 and 1.00. Improvement of the negative EB at the beginning of lactation requires measures of EB or EB traits in the energy deficit phase, because EB in early lactation and mid lactation are negatively correlated. Considering these findings, daily relative breeding values for EB and FPR from day 11 to 42 were averaged, grouped and related to relative breeding values for health traits (see Figure 2).

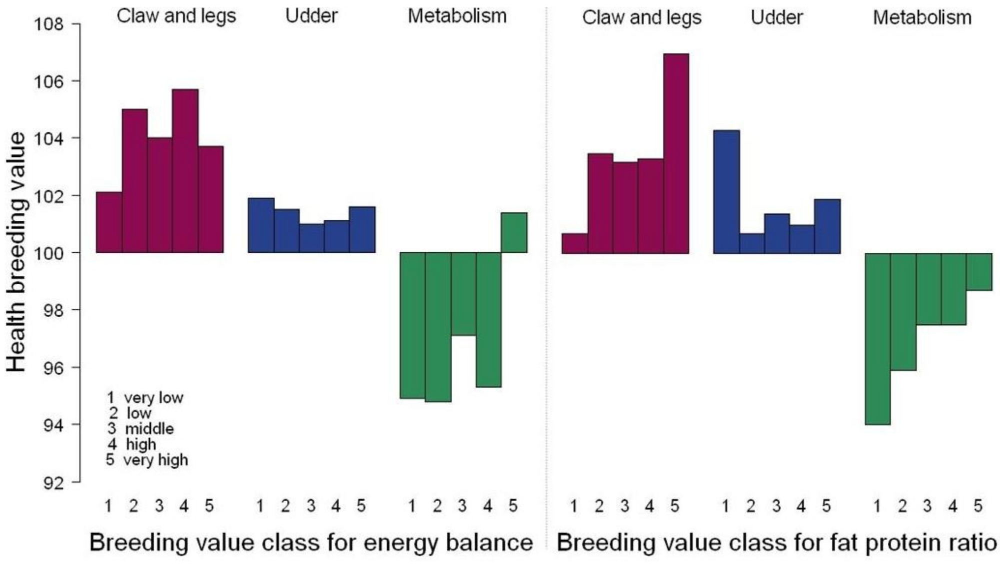

Figure 2: Average relative breeding values for health traits plotted against breeding value classes for energy balance and fat protein ratio of milk, respectively

Heifers with extremely low EB breeding values also had the worst average breeding values for claw and leg health. Mastitis liability seems to be unaffected by EB. The closest relationship was found between EB and metabolic stability. The heifer group with the best EB breeding values was the only group with positive average breeding values for metabolic stability. This result indicates that only strict selection on EB will lead to less metabolic disorders. Selection on FPR would be more effective than selection on EB if the objective is to improve claw and leg health. In contrast to EB, FPR was slightly unfavorable related to mastitis. However, the relation was nonlinear. The relationship between FPR and metabolic health was more clearly compared to the association between EB and metabolism. The higher the FPR breeding value, the better the average breeding value for metabolic health.

Conclusion

The results suggest that metabolic disorders and claw and leg diseases could be reduced by selection against severe energy deficits *post partum*, whereas mastitis liability seems to be unaffected by EB status. The FPR is a suitable EB indicator trait at the beginning of lactation and a potential variable to differentiate between cows that can or cannot adapt to the challenge of early lactation.

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