GENETIC VARIATION IN ELECTRICAL CONDUCTIVITY IN MILK AND CORRELATION WITH SOMATIC CELL SCORE

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INTRODUCTION

During the last decades electrical conductivity (EC) in milk has been introduced as an indicator trait for mastitis. Electrical conductivity is determined by the concentration of anions and cations, where Na⁺, K⁺ and Cl⁻ are the most important ions. If the cow suffers from mastitis, the concentration of Na⁺ and Cl⁻ in the milk increases (Kitchen, 1981). This leads to increased EC in milk from infected quarters, and it might be possible to detect the sick quarter by comparing it with the healthy quarters. Measuring EC during milking on each quarter is relatively cheap and easy and such information can be useful to prevent or detect mastitis at an early stage. Besides using EC as a management tool, it might be a possible indicator trait in a health index for dairy cattle. To be a valuable information source to include in the index, EC must express genetic variation and be correlated to the traits in the breeding goal for udder health. Estimates on genetic parameters in the literature are scarce. The aim of this study was to estimate heritabilities for EC and correlation with somatic cell score (SCS) based on records from first lactation cows in an experimental herd.

MATERIAL AND METHODS

Design and Animals. The experiment took place in an experimental herd, consisting of Holstein, Danish Red and Jersey cattle, with approximately 110 cows at any time. Each breed was divided into two selection lines, by use of separate panels of bulls. Cows in each line were randomly assigned to either a normal or a low energy density total mixed ration. All cows were fed ad lib. Data obtained from January 1997 to December 2000 from about 250 first lactation cows were included in this study. This gave a total of 2633 animals in the pedigree file. Milk yield and parameters were recorded at every milking (2xday), and a total of 11233 milkings were included.

Somatic cell counts (SCC) and EC data. Samples of milk were collected at each milking and analysed for SCC (Combi-Foss 4000, Foss-Electric, Hillerød, Denmark). Somatic cell counts were log-e transformed to somatic cell score (SCS) before further analysis. Electrical conductivity was measured in milliSiemens (mS) in milk from each quarter during every milking at 2 second intervals using a prototype computerised milkmeter, combined with a prototype “Mastitis detector” (S.A. Christensen, Kolding, Denmark). This resulted in 4 EC profiles from each milking. Figure 1 shows EC profiles for a cow where the right back quarter is infected, and it shows a significantly higher EC value than the others. As the higher EC levels are supposed to indicate mastitis, a smoothed maximum value was obtained for each quarter using an algorithm giving a weighted rolling average (RA_ECQ) according to [1]. ECQ is the following registration, and to be included in the rolling average at time t it has to be...
higher than the calculated RA_ECQ at time (t-1).

\[ RA_{ECQ_t} = 0.85*RA_{ECQ_{t-1}} + 0.15*EC_{t} \]

The quarter with the lowest EC value was supposed to be most healthy, and used as a reference. A ratio was calculated between each quarter and the reference quarter, and at each milking the highest ratio gave the “alarm-value” of the cow.

Figure 1. Electrical conductivity during milking measured on each quarter

Statistical analysis. Data was analysed uni- and bi-variate using the following random regression (RR) model [2] :

\[ Y = Xb + Z_t \tau + Z_p \pi + Z_a \alpha + \epsilon \]

where \( b \) is a vector of fixed effects of breed, feeding level, calving season and stage of lactation modelled as normalised Legendre polynomial (LP). The random effects \( \tau, \pi, \alpha \) and \( \epsilon \) are test day, permanent environment, additive genetic and residual, respectively. \( X, Z_t, Z_p \) and \( Z_a \) are design matrices relating the effects to records. In initial univariate analysis the permanent environment effect and the additive genetic effect were modelled as forth order LP’s. Based on restricted log likelihood ratio tests, the permanent environment effect could be modelled sufficiently by a 0’th order LP (i.e. a constant effect during the lactation). Due to convergence problems in the bivariate model, the additive genetic effect was reduced to a 1’st order LP (i.e. a constant and a linear term). The analyses were performed by the AI-REML algorithm (Jensen et al., 1996/97) using the DMU package (Madsen and Jensen, 2000).

RESULTS AND DISCUSSION
The lactation curve for SCS showed an initial high value in the beginning of lactation, followed by a decline to a stable level from day 150 to almost the end of lactation. This corresponds well with the literature (Dohoo and Meek, 1982). The EC value on the reference quarter was quite stable during lactation, while the quarter with the highest EC value showed the same trend as SCS. The EC “alarm-value” showed only minor changes during the lactation, with a slight increase (Figure 2). Sheldrake et al. (1983) found an increase in both SCS and EC from 35 to
300 days in lactation, while Matje et al. (1992) contrarily found that EC on healthy quarters decreased as lactation progressed.

![Figure 2. Changes during lactation in SCS and EC “alarm-value”](image)

Heritabilities of EC “alarm-value” were slightly lower than corresponding values for SCS through lactation, and it was estimated to about 0.1 in early lactation and increased to 0.3 in the last half of the lactation (Figure 3). These results coincide with Goodling et al. (2001) which found heritabilities for composite milk EC ranging from 0.27 to 0.39 in 1. lactation. Heritabilities for SCS were about 0.2 in early lactation, and stabilised at 0.3 in the last half of the lactation. These estimates are slightly higher than reported in a review by Emanuelson (1988). Estimates of heritability based on morning and afternoon milkings in separate analysis were similar and thus support each other.

![Figure 3. Heritability of EC “alarm-value” and SCS during lactation](image)

The correlation between EC and cell count was estimated using a bivariate approach, which only allowed using a linear term in the random regression part of the model. The genetic
correlation increased from about 0 early in the lactation to about 0.5 for morning milking and from 0 to about 0.25 for evening milking until day 150, and then stayed stable the rest of the lactation (Figure 4). The differences in $r_c$ between morning and evening milkings might be due to estimation errors or different expressions of the traits. Since the EC values are based on an inter quarter ratio it seems to be less influenced by environmental factors compared to SCS. Previous studies show that SCS is highest in the evening (Dohoo and Meek, 1982). The phenotypic correlations between morning and evening milkings were similar, and increased slightly during the lactation. Goodling et al. (2001) estimated correlation among sire solutions for EC and PTA SCS to be 0.3, and regression of daughter EC on sire PTA SCS to be 0.8.

![Figure 4. Genetic ($r_c$) and phenotypic correlation ($r_p$) between EC “alarm-value” and SCS during first lactation](image)

**CONCLUSION**

The results from this experiment show that electrical conductivity in milk is a moderately heritable trait, and it is positive correlated to somatic cell score. Due to the positive correlation between SCS and mastitis, it might be possible to select on EC to improve mastitis resistance in dairy cattle. Measurements can be performed on the farm during milking, and registrations on each quarter can easily be done.

**REFERENCES**