Adjusting early lactation somatic cell count for assessment day in predicting heifer culling hazard

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Abstract

The somatic cell count (SCC) of dairy heifers is a surrogate marker for udder health. Therefore, we investigated the effect of the somatic cell count shortly after parturition on the culling hazard. The somatic cell count, however, was only assessed once for each heifer and at different days varying from 5 to 14 days after parturition (DAP). It is well established that SCC decreases in the early days after parturition so that an adjustment is required for the assessment day (Dohoo, 1993).

Objective
We investigate different alternative modelling techniques within the Cox model framework to adjust for the day of assessment, such as stratification and covariate adjustment, whereby we explicitly model the effect of the assessment day on SCC.

Materials and Methods

A large database consisting of 14,234 heifers from 3264 herds (enrolled in the Belgian DHI program; Flemish Cattle Breeding Association, Oosterzele, Belgium) was used to evaluate the results of the different models (Devlieger et al., 2006).

The most straightforward way of adjusting is to add DAP into the model as a continuous fixed effect, resulting in Model (1)

$$h_{ij}(t) = h_0(t)\ \exp\left(\mathrm{d}\ (i-5) + \mathrm{b}\ \log\left(SCC_{ij}\right)\right)$$

with $h_{ij}(t)$ the hazard at time t of heifer j with DAP i, $h_0(t)$ the baseline hazard, d the effect of DAP and b the effect of log(SCC_{ij}). Not that we subtract 5 from i, the particular value for DAP, so that the covariate value zero corresponds to day 5 after parturition, the first day on which SCC was assessed. This model, however, implies that DAP has an effect on the culling hazard, which is biologically meaningless.

A first alternative is to adjust log(SCC_{ij}). The adjustment can be based on the general linear relationship between DAP and log(SCC) with estimated slope $\hat{a}$, resulting in Model (2)

$$h_{ij}(t) = h_0(t)\ \exp\left(\mathrm{b}\ aSCC_{ij}\right)$$

with $aSCC_{ij} = \log\left(SCC_{ij}\right) - \hat{a}\ (i-5)$.

A second alternative is to stratify according to DAP, resulting in Model (3)

$$h_{ij}(t) = h_{i0}(t)\ \exp\left(\mathrm{b}\ \log\left(SCC_{ij}\right)\right)$$

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with a different baseline hazard $h_{i0}(t)$ at each DAP, so that only heifers with the same DAP are directly compared.

An extension of this model is to assume a different effect of SCC at different DAP resulting in Model (4)

$$h_{ij}(t) = h_{i0}(t)\ \exp\left(\beta_i \log\left(SCC_{ij}\right)\right)$$

All these models can be fitted through partial likelihood maximisation.

Results

In Model (1) with DAP and log(*SCC*) as continuous covariates, both DAP (p=0.004) and log(*SCC*) (p<0.0001) have a significant influence on the culling rate. The estimated hazard ratio for 1 day increase in DAP equals 1.02 (95% CI: 1.01-1.03) and for 1 log-unit increase in *SCC* 1.10 (95 % CI: 1.07-1.14). As noted before, however, the effect of DAP on the culling rate does not make sense biologically, it has an indirect effect through the change of SCC as a function of time after parturition.

For Model (2), the estimate for α equals -0.083. Based on $\hat{\alpha}$, adjusted values of the log(*SCC*) covariates are obtained and used in the model, leading to the same estimate for the hazard ratio equal to 1.10 (95 % CI: 1.07-1.13) as in Model (1).

With DAP as a stratification factor in the model (Model 3), the hazard ratio for log(*SCC*) is again estimated to be equal to 1.10 (95 % CI: 1.07-1.14). The extended model with a hazard ratio for each specific DAP value (Model 4) fits the data significantly better (likelihood ratio test, p<0.0001). The estimated hazard ratios from day 5 to day 14 DAP correspond with 0.95, 1.02, 1.08, 1.07, 1.06, 1.13, 1.08, 1.23, 1.17, 1.18 respectively. Hazard ratios are higher in the second half of the days of assessment with the highest hazard ratio equal to 1.23 for DAP equal to 12.

Conclusions

Overall, log(*SCC*) shortly after calving has a significant effect on the culling hazard. The strength of the relationship, however, depends on the day that log(*SCC*) was measured, with a stronger relationship appearing from DAP 10 onwards. Therefore, the model should be able to cope with the fact that the relationship changes with DAP.

The model with DAP as a continuous variable, together with log(*SCC*) has a major disadvantage in that the parameter estimate for the effect of DAP on the culling hazard does not make sense. The parameter estimate describes the effect of DAP on the culling hazard, but there is no reason why the day of assessment should have an effect on the culling hazard. We have, however, found a significant effect of the day of assessment. This is, however, not due to the fact that the day of assessment has an effect on the culling hazard, but rather on log(*SCC*). Thus, culling hazard information is used to adjust for the fact that log(*SCC*) is evolving as a function of DAP. But this evolution of *SCC* is a physiological phenomenon that has nothing to do with the culling hazard and therefore we believe this adjustment technique should not be used as it does not describe the biology of the phenomenon correctly.

The stratified model is the preferred model as it can be extended to investigate whether the effect of risk factors differs from stratum to stratum. The extended stratified model led to the important conclusion that log(*SCC*) is mainly a good predictor for culling hazard when assessed between 10 and 15 days, and not before that period.

References

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