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Genetics evaluation for longevity in Slovenian Simmental cattle

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ABSTRACT

A maternal grandsire model (sire-mgs model) using survival analysis was used to estimate fixed and to predict random effects in genetic evaluation for longevity of Slovenian Simmental population. Longevity was described as length of productive life (LPL). The culling frequency increases with lactation duration with the culling peak at the lactation end. At the end of second lactation, most cows were culled, while the number of culled cows decreases in subsequent lactations. Most culled cows first calved at the age of 26 to 30 months and the relative culling risk increases with the increase of age at first calving. The cows that are breed in herds with decreasing size are more likely to be culled. Determined minimal differences in estimated breeding values between analysed birth years indicate that in the period from year 1965–1998 selection for longevity was not conducted. In the period from year 1998 to year 2004 relatively high differences between average estimated sires BV for longevity per birth year were observed which could not be taken as accurate presentation BV because of the small number of data per sire. As the genetic evaluation accuracy highly depends on ratio of censored and uncensored records and also on number of daughters per evaluated sire, further research with the purpose to detect the impact of censored records proportion on accuracy of genetic evaluation as well as the determination of number of daughters per sire sufficient for accurate evaluation is necessary.
(Keywords: cattle, Slovenian Simmental, longevity, Weibull proportional hazards model)

INTRODUCTION

Longevity is a trait with great impact on dairy production economy and is therefore of considerable importance in dairy cattle breeding programmes (*Charffeddine et al.,* 1996; *Strandberg and Soelkner,* 1996). With the increase of longevity, the proportion of mature cows that produce more milk increases. For example, *Strandberg* (1996) estimated that an increase in longevity from three to four lactations increases average milk yield per lactation and profit per year by 11 to 13%. In addition, improvement in longevity decreases replacement costs and somewhat increases selection intensity.

The aim of this study was to present the results of genetic evaluation for the length of productive life in Slovenian Simmental population using a Weibull proportional hazard model.

Review of literature

There are several ways to implement longevity in the breeding goal, directly or indirectly. Direct longevity can be represented as the length of productive life (LPL) or stayability. In cattle breeding LPL is usually defined as the elapsed time between the first calving and culling, while stayability is defined as a binary trait that measures cow survival (live or culled) at certain point in time. The use of LPL is preferred since stayability as a discrete trait provides less information. Unfortunately LPL, as well as stayability, can be quantified only after the cows are culled, though both approaches provide partial information when cow survives to the next "period" in life. Therefore, the information on the longevity of daughters of a sire becomes available with the increasing age of a sire. This inherently leads to the prolonged generation interval. Low heritability for longevity (*Short and Lawlor,* 1992; *Vollema and Groen,* 1996) induces unreliable estimation of breeding values (BV) based on the information of parents or grandparents.

Due to a long generation interval, breeding programmes also include indirect measure of longevity via correlated traits such as fertility, health, and conformation traits (*Burnside et al.,* 1984). Additional gain is due to the fact that the data on these indirect traits can be collected relatively early in the life of a cow. Nonetheless, both representations of longevity (direct and indirect) have a merit in a modern breeding goal (*Essl,* 1998).

Analysis of indirect representations of longevity is to a large extent done with a standard linear model based on the Gaussian (normal) distribution. Specific approach is needed for a proper analysis of the LPL, due to the presence of live animals at the time of analysis (censored records) and changes in culling criteria over the productive life of cows (time-dependent effects) (*Ducrocq et al.,* 1988). Exclusion of censored records from the analysis, or treating them as uncensored would lead to biased results (*Ducrocq,* 1994). Additionally, the mode of relationship between longevity and its effects is rather multiplicative than additive (*Ducrocq et al.,* 1988). Survival analysis can handle this kind of data. In the last years several countries introduced direct longevity in the routine genetic evaluation of cattle and most of them use the Weibull proportional hazard model (*INTERBULL,* 2009), which represents a class of models in the field of survival analysis. Other statistical approaches (models) can also be used, but proportional hazard model have better properties (*Caraviello et al.,* 2004; *Jamrozik et al.,* 2008).

MATERIALS AND METHODS

Raw data for 142,989 Slovenian Simmental cows born from 1980 to 2008 were provided by the Agricultural Institute of Slovenia. In order to use old data but to avoid modelling the data up to the year 1991, the truncation date was set at January 1st 1991. On the other side, the date of last data collection was January 29th 2010. For cows alive at that time longevity was treated as right censored. Longevity was defined as the length of productive life (LPL) and was calculated as the number of days from the first calving to culling (uncensored/complete records) or to the moment of data collection (incomplete/censored records). The LPL of cows surviving beyond the sixth lactation was also censored in order to avoid the effect of preferential treatment and to focus on early culling in the life of a cow. Cows with missing or inconsistent data within the defined limits were removed (51,412 cows): culling before the date of truncation, calving date after the date of culling, no information for 600 days after calving, missing data for the first three lactations, daughters of sires with less than 20 daughters, and missing covariate or factor data.

Altogether LPL for 125,468 cows from 6791 herds were used in the analysis. Cows in the analysis were daughters of 686 sires. MGS pedigree included 1903 sires. Cows were on average culled between 3rd and 4th lactation, which amounted to 1212 day of productive life. Percentage of censored records was 44.9%.

Weibull proportional hazards model was used for the analysis of LPL. This model is built upon the Weibull distribution, whose density (1) and hazard (2) function for the i-th record are:

$$f(t_i \mid \lambda, \rho) = \lambda\rho(\lambda t_i)^{\rho-1} \exp\left(-(\lambda t_i)^{\rho}\right) \tag{1}$$

$$h(t_i \mid \lambda, \rho) = \lambda\rho(\lambda t_i)^{\rho} \tag{2}$$

where λ (scale) and ρ (shape) are strictly positive parameters. In proportional hazard model it is assumed that the baseline hazard function changes proportionally with change in covariate(s) or factor levels. For the analysis of LPL the hazard function was modelled as:

$$h(t_{ijklmnop} \mid \lambda, \rho, else) = h_0(t_{ijklmnop} \mid \lambda, \rho) \exp\left(c_i + l_j + y_k + h_l + d_m + s_n + 1/2\, s_o\right) \tag{3}$$

where:

- the hazard function of culling the p-th cow given all parameters,
- the baseline Weibull hazard function (2),
- the time-independent effect of the i-th age at the first calving: 0 (unknown) and from 19 to 50 months,
- the time-dependent effect of the j-th lactation stage (1−60 days, 61−150 days, 151−270 days, 271-days till drying, and dry period) within parity - altogether 30 levels,
- the time-dependent effect of the k-th season defined as year (1990–2009),
- the time-dependent effect of the l-th herd (3891 levels),
- the time-dependent effect of the m-th herd size deviation in comparison to previous year (≤-70%, (-70%, -40%], (-40%, -10%], (-10%, 10%], (10%, 40%], (40%, 70%], and >70%),
- the time-independent effects of the n-th sire and the o-th maternal grandsire (onwards both effects are termed sire effect) of the p-th cow.

Levels of time-dependent effects changed with cow "status" changes in time, while levels for time-independent effects were constant over whole lifetime of a cow. Altogether, there were 2,644,036 elementary records. Herd and sire effects were modelled hierarchically: log-gamma distribution for herd effect and multivariate normal for sire effect with additive genetic covariance matrix among sires.

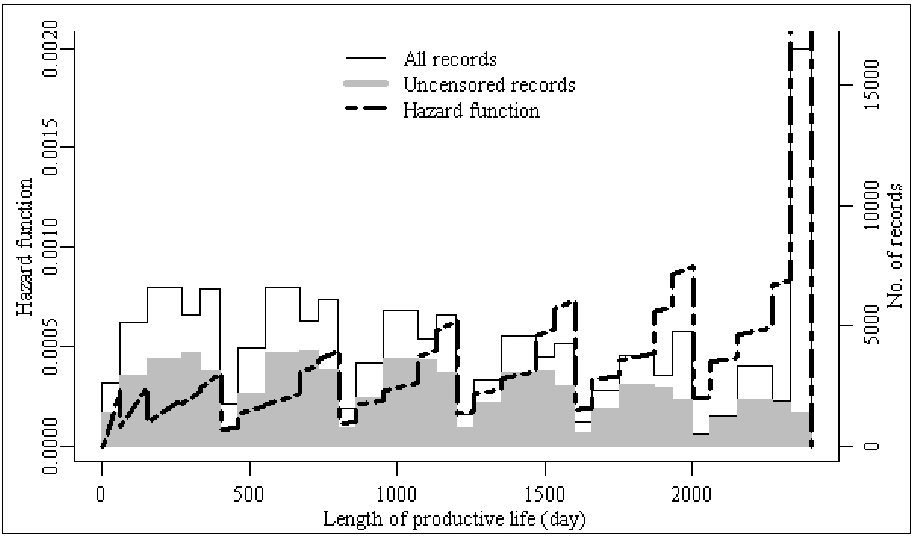
Data processing was done with SAS software package (*SAS Institute,* 2000), while Survival Kit version 3.10 (*Ducrocq and Soelkner,* 1998) was used for modelling and parameter estimation. In the first step a series of log-likelihood ratio tests were performed for effects that were not modelled hierarchically – importance of each effect was tested as a comparison between the full model and the model where the effect under testing was excluded. In the next step herd and sire effect were added to the model to obtain estimates for all model parameters.

RESULTS AND DISCUSSION

All effects included in the model were highly significant (P<0.001) which is not surprising given the size of data set and the previous knowledge of effect importance for LPL. Estimates for relative risk of culling according to the effect of lactation stage within parity are shown in *Figure 1.* It could be noticed that one year after calvings that is at the end of lactation periods cullings are most frequent.

Figure 1

Relative risk of culling and number of records by stage of lactation within parity



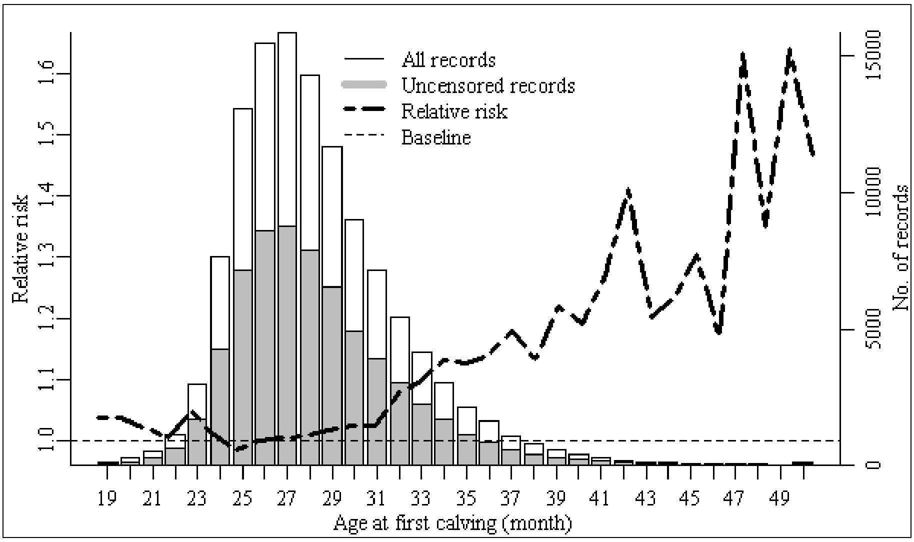
The intervals between the culling peaks are about 400 days which are equal to average calving interval in Slovenian Holstein cows. In respect to parity, most cows were culled at the end of second lactation, then at the end of third, first and fourth lactation. The number of culled cows decreases in subsequent lactations. Line at the figure that connects estimates of effect classes shows culling frequency during each lactation. In all lactations, with exception of the first one, culling frequency increases with lactation duration with culling peak at the lactation end.

Vukasinovic et al. (1997) determined that the relative culling rate is larger during the first lactation than during later lactations. They also determined that within each lactation, the relative culling rate varies significantly that is a cow finishing a lactation is at much higher risk of being culled than an identical cow in early or midlactation, because the dry period is the period of the most intensive selection in dairy herds. They also noticed that the risk of being culled increases up to 2 months after calving, which might be due to a higher incidence of health disorders during early lactation.

According to age at first calving, the proportion of culled cows increases till the age of 27 months, after what decrease is determined. Most culled cows first calved at age 25 to 29 months (*Figure 2*). Relative culling risk increases with increase of age at first calving. *Vollema and Groen* (1998) determined that effect of age at first calving on culling risk was significant ($P<0.001$) and positive indicating that cows that are older at first calving have a higher risk of being culled. *Ducrocq et al.* (1988) and *Ducrocq* (1994) in statistical analysis of length of productive life for dairy cows determined that the effect of age at first calving was not significant. *Rogers et al.* (1991) in analysis of survival of Jersey breed found that productive life decreased with age at first calving. *Syrstad* (1979) showed that survival rates of cows declined dramatically over 34 months of age at first calving and concluded that an intermediate age at first calving was associated with the highest LPL. *Vukasinovic et al.* (1997) tested the significance of the explanatory variables using a likelihood ratio test for large samples and stated that the change in log likelihood that was associated with the age at first calving was very small compared with that of the other effects analysed in their study. Therefore, they considered this effect as unimportant.

Figure 2

Relative risk of culling and number of records by age at the first calving

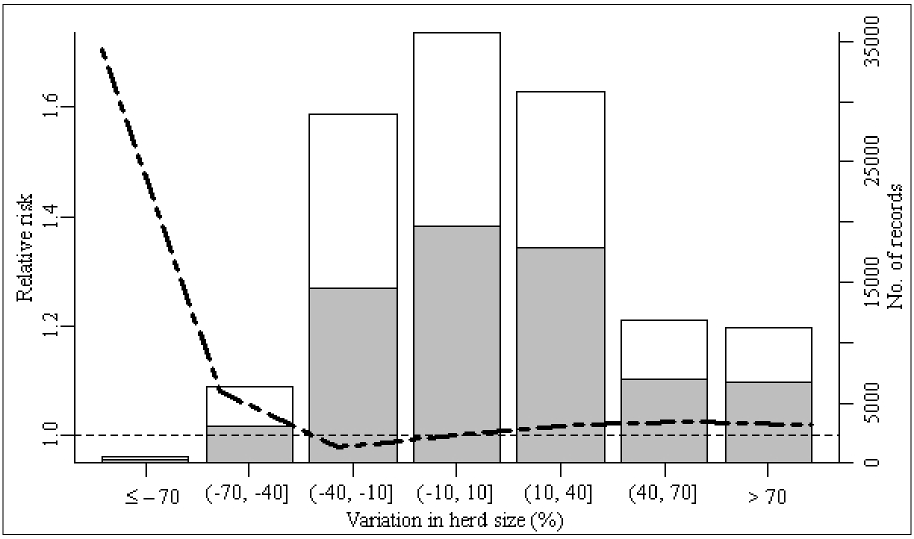


According to classes of deviation in herd size across years, highest proportions of culled cows were determined in 4. class [40%, 70%], while the highest culling risk was noticed in 1. class [min, -70%] meaning, as expected, that the cows that are breed in herds with decreasing size are more likely to be culled (*Figure 3*). *Weigel et al.* (2002) calculated the relative culling risk of high producing (top 20%) and low producing (bottom 20%) cows relative to average cows in the same herd in regard to changes in herd size. They determined that, before herd expansion, low producing cows were 4.2 times more likely to be culled than average cows, while high producing cows were only 0.5 times as likely to be culled as average cows. After herd expansion, the relative risk for low producing cows dropped to 2.6 times that of average cows, and the risk for high producing cows increased to 0.7 times that of average cows. This indicate that in expanding herds more high producing cows are culled due to involuntary culling and fewer low producing cows could be culled due to low milk production. Same authors also reported that relative risk of involuntary culling of high producing cows (as compared with average cows) in expanding Wisconsin herds depends of the herd size that is in larger herds (>150 cows) is higher (0.71) than in smaller herds (<150 cows; 0.62).

Based on the used statistical model, sire variance in amount of 0.030, and herd variance in amount of 0.199 were estimated. Estimated heritability value in amount of 0.098 was similar to values estimated in the Nederlands (*INTERBULL,* 2009) and joint evaluation for Austria and Germany (*Fuerst and Egger-Danner,* 2002 and relative low in comparison of this parameter estimated in Switzerland (0.198) (*Vukasinovic et al.,* 2001).

Figure 3

Relative risk of culling and number of records by levels of variation in herd size



The genetic evaluation accuracy highly depends on ratio of censored and uncensored records. As the proportion of censored records decreases, the evaluation accuracy increases. Also, it is necessary to have sufficient number of daughters per sire. *Vukasinovic et al.* (1997) stated that more than 30 to 40% of censored records would lead to inaccurate results. Same authors reported that small number of daughters per sire without any or with only few uncensored records would bias the sires ranking according to estimated transmitting abilities (ETA). *Egger-Danner et al.* (1993) in their study compared the ranking of sires according to ETA from the full data file without censored records and from truncated data with a different proportion of censored records and observed that rank correlations between ETA on the full data file and on the censored data were lower as the proportion of censoring increased.

Further research with purpose of detection of the impact of censored records proportion on accuracy of genetic evaluation as well as the determination of number of daughters per sire sufficient for accurate evaluation is necessary.

CONCLUSIONS

Appliance of survival analysis provide usage of uncensored and censored records what makes this method adequate to use for analysis of productive life data. Based on the conducted research it could be concluded that all effects included in used statistical model (time-independent fixed effect of time from 1st calving to the culling or to the moment of data collection or till the end of sixth lactation; time-independent fixed effect of lactation stage within parity; time-independent fixed effect of age at first calving; time-dependent fixed effect of year; time-dependent fixed effects of herd size class; time-dependent random effect of herd and time-independent random genetic effect of sire) have significant effect on LPL. The most important effects on LPL are lactation stage and parity, age at first calving, as well as the effect of changes in herd size across years.

The culling frequency increases with lactation duration with culling peak at the lactation end. At the end of second lactation, most cows were culled, while the number of culled cows decreases in subsequent lactations. Most culled cows first calved at the age of 25 to 29 months and the relative culling risk increase with increase of age at first calving. The cows that are bred in herds with decreasing size are more likely to be culled. Based on used statistical model, sire variance in amount of 0.030, herd variance in amount of 0.199 as well as heritability value in amount of 0.098 were estimated.

The genetic evaluation accuracy highly depends on ratio of censored and uncensored records and also on number of daughters per evaluated sire, therefore further research with purpose of detection of the impact of censored records proportion on accuracy of genetic evaluation as well as the determination of number of daughters per sire sufficient for accurate evaluation is necessary.

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