Genetic evaluation of the length of productive life in Holstein cattle in the Czech Republic

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ABSTRACT: Survival Kit V3.12 was used to analyse the length of productive life of cattle in the Czech Republic. The data set consisted of 230 028 registered Holstein cows. The model included the time-dependent effects parity × stage of lactation interaction, herd × year × season interaction, class of milk production within herd and year, breed within years and the time-independent effect of age at first calving and the random effect of sire. The highest risk of culling was found for cows at the beginning and at the end of the first lactation and at the end of any other lactation. The risk of culling decreased with parity. The risk of culling of cows assigned to the lowest milk production class was five times higher than that of cows assigned to the average milk production class. Risk of culling diminished with a decreasing percentage of Holstein breed. Cows younger at first calving showed a lower risk of culling. Breeding values for sires expressed as a risk ratio of their daughters were between 0.7 and 1.45. Estimated heritability of functional longevity was 0.025 on the log scale and 0.041 on the original scale.

Keywords: length of productive life; cattle; survival analysis; heritability

Together with fertility and type traits, length of productive life (LPL) is currently the most important functional trait in cattle breeding. The highest effect of longer productive life decreases the costs of replacement. Longer productive life also leads to a higher proportion of cows that are in later, high producing lactations (Vukasinovic et al., 1997).

The length of productive life is defined as the number of days from the first calving to culling, death or censoring. In this context censoring means that the animal was still alive at the time of analysis or the loss of follow-up, i.e. the fate of an animal after a certain point in time was unknown. Functional longevity, which depends on the ability of the cow to avoid culling for involuntary reasons such as sterility or disease (Ducrocq, 1987), was used.

The implementation of survival analysis techniques in statistical analysis and genetic evaluation for longevity enabled to carry out appropriate analyses of longevity data (Vukasinovic et al., 1999). Survival analysis uses complete available information on both uncensored and censored records, provides a proper statistical treatment of censored records, and allows for changes in culling policy over time.

Hazard of culling is defined as the product of the baseline hazard function and the function of variables affecting longevity. The results for fixed effects are expressed as relative culling rates, defined as the ratio between the estimated risk of culling under the influence of a certain environmental factor and the average risk which is usually set to one. Values higher than one indicate a higher culling risk associated with the environmental factor. Relative culling rate lower than one indicates a lower culling risk, i.e. increasing effect of the environmental factor on longevity (Vukasinovic et al., 2001). Boettcher et al. (1999) reported that the survival analysis also tended to give higher estimates of heritability than did the linear model when both estimates were expressed on the linear scale.

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The aim of the study was to analyze the main effects influencing the longevity of Holstein cattle and to propose a method of estimation of breeding values for longevity in the Czech Republic.

MATERIAL AND METHODS

The data set available for analysis included records from 230 028 registered Holstein cows in milk recording that were daughters of 827 sires. Sires were required to have at least 25 daughters in the data set. The cows were from 828 herds with first calving from January 1, 1990 to April 30, 2004. Records of cows that were still alive at the end of the study were treated as right censored (19.5%).

Age at first calving was restricted between 500 and 1 100 days for the 1st lactation and between 800 and 1 600 days for the 2nd lactation. Cows with missing date of the first calving were excluded from the data set.

The size and some other characteristics of the employed data set are presented in Table 1.

A set of programs Survival Kit V3.12 (Ducrocq and Sölkner, 1998b), Weibull model, was used for analysis.

Table 1. Structure of the data set

Number of uncensored records	185.453
Minimum LPL (days)	10
Maximum LPL (days)	4.631
Average LPL (days)	923
Number of censored records	44.575
Minimum censoring time (days)	102
Maximum censoring time (days)	5.215
Average censoring time (days)	1.089

The following effects were taken into account in the model:

$$h(t, z) = h_0(t) \times \exp\,[\text{hys} + \text{pst} + \text{ml} + \text{yb} + \text{age1} + \text{sire}]$$

where: $h(t, z)$ = hazard of the cow, t days after her first calving

$h_0(t)$ = Weibull baseline hazard function at time t

hys = random time-dependent effect of the herd × year × season interaction with changes of year every 1st January and with changes of season on 1st January, 1st April, 1st July, and 1st October. The effect is assumed to follow a gamma distribution and is integrated in the model (38 885 levels), therefore no solution was obtained. A similar approach was used by Vollema and Groen (1998)

plst = fixed time-dependent effect of the parity × stage of lactation interaction. Parity had 7 classes (1, 2, 3, 4, 5, 6, 7+) and the stage of lactation included 4 classes with changes at calving and at the 60th, 180th and 240th days after calving

ml = fixed time-dependent effect of the class of milk production within the herd and year. The effect had 6 classes which changed after each calving. Milk classes are described in Table 2

yb = fixed time-dependent effect of breed within years. The proportion of Holstein genes had five classes (100%, 80–99%, 70–79%, 60–69%, less than 60%)

age1 = time-independent effect of age at the first calving with 7 classes according to age at the first calving in days. Classes of age at the first calving are described in Table 3

sire = random genetic effect of sire. Sire effects were assumed to follow a multinormal distribution. The relationship between sires was accounted for by the inclusion of a sire-maternal-grandsire relationship matrix

In the described model the following classes of the effects were set to one: interaction of the 1st parity and 4th stage of lactation, 3rd class of milk production within herd and year, interaction of 1st class of Holstein genes with the year 2003 and 5th class of age at first calving.

The heritability on the log scale was calculated (Korsgaard et al., 1999; Vukasinovic, 1999) as:

$$h^2_{\log} = 4\text{Var(s)}/(\text{Var(s)} + \pi^2/6)$$

and the heritability on the original scale (Yazdi et al., 2002) as:

$$h^2_{\text{orig}} = 4\text{Var(s)}/(\text{Var(s)} + 1)$$

Table 2. Classes of milk production within the herd and year in standard deviations (SD) intervals

Class	SD interval	Number of uncensored records
1	less than –1.5	24 919
2	–1.5 to –0.5	44 314
3	–0.5 to 0.5	54 728
4	0.5 to 1.5	29 457
5	more than 1.5	6 478

Table 3. Classes of age at first calving

Class	Interval (days)	Number of uncensored records
1	missing value	998
2	less than 750	21 839
3	750 to 780	21 443
4	781 to 830	41 834
5	831 to 900	48 811
6	901 to 960	26 730
7	more than 961	23 798

RESULTS AND DISCUSSION

All effects included in the model were significant (*P* < 0.001). The highest risk of culling occurred for cows at the beginning of the first lactation and at the end of first lactation as well as at the end of any other lactation. Results are shown in Figure 1. The results reflect the selection strategy in herds. At the beginning of the first lactation (from calving to 60 days of lactation) the main culling reason is voluntary: bad start in milk production. At the end of lactations (after 240 days of lactation) there is also some voluntary culling for low lactation milk yield but also involuntary culling for reproduction and health problems. Roxström et al. (2003) reported that the first lactation differed from later lactations which were all roughly parallel. Vukasinovic et al. (1997) expected that a cow finishing lactation was at a much higher risk of culling than the identical cow in early or mid lactation because the dry period is the period of the most intensive selection in dairy herds. Similar results were published by Ducrocq et al. (1988). According to Vukasinovic et al. (2001), the first lactation deviates from the typical pattern because of the increased hazard at about 60 days after first calving. It indicated different selection criteria in first lactating cows.

In our study the risk of culling decreased with parity (Figure 1). In the Czech Republic herd replacement is high (the average number of lactations per Holstein cow is 2.7, Přibyl and Přibylová, 2001). The cow that survives to the second lactation or to further lactations has a lower risk of culling because it overcame the wiles of the first lactation. The first lactation is a proof of the cow's abilities. Vukasinovic et al. (1997) described a trend of higher relative culling rate during the first lactation than during later lactations. On the other hand, according to Vukasinovic et al. (2001) the estimated hazard for parity remained approximately constant in the first four lactations and increased gradually after that point.

Cows being younger at first calving had a lower risk of culling than the older ones. Results are shown in Figure 2. We can speculate that the higher age at first calving is a signal of fertility or other health problems of the cow. Sewalem et al. (2005) found that the effect of age at first calving did not have a large influence on LPL although a linear increase of relative culling risk was observed as the age at first calving increased. The same results were published by Vukasinovic (1999), Vollema et al. (2000) and Nilforooshan and Edriss (2004).

The cows with the lowest class of milk production had a five times higher risk of culling than cows with average milk production, as shown in Figure 3. We found that the class of milk production within year and herd was the most important effect af-

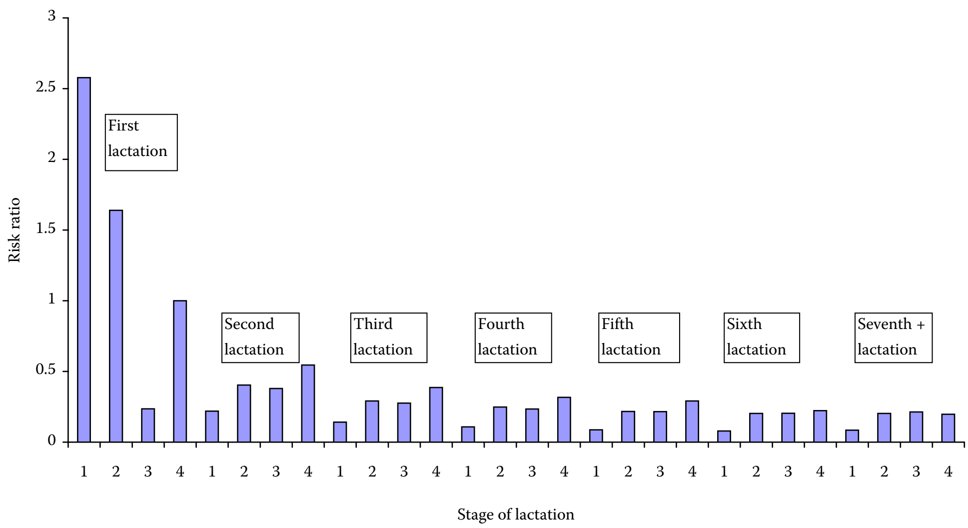

Figure 1. Estimates of the effect of lactation number × stage of lactation interaction

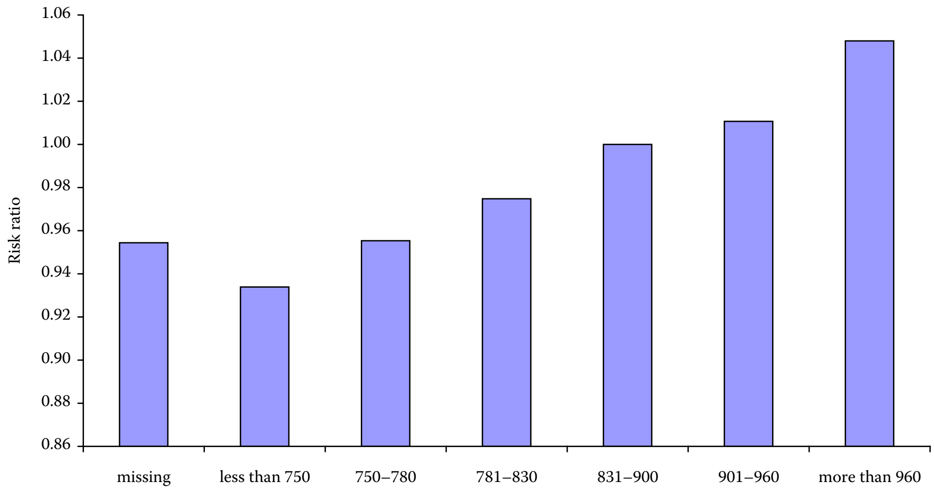

Figure 2. Estimates of the effect of class of age at first calving

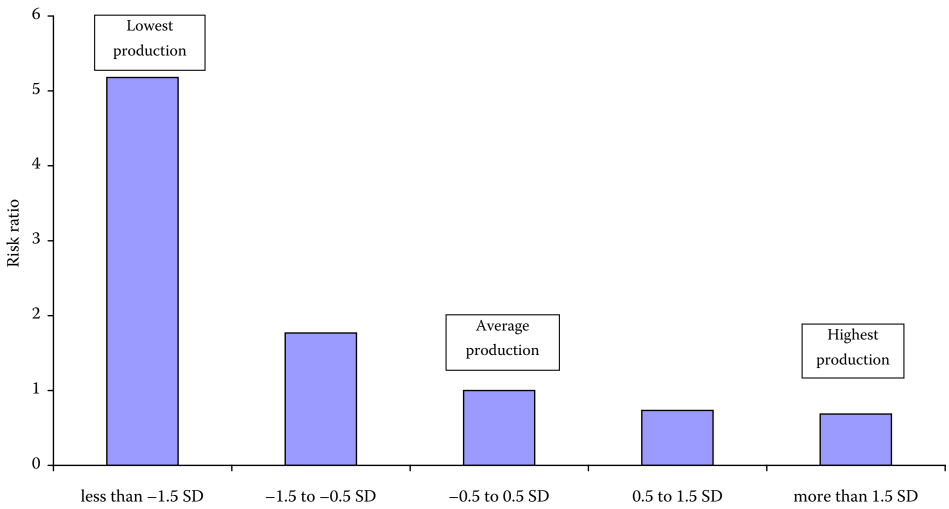

Figure 3. Estimates of the effect of class of milk production

fecting LPL. Vukasinovic et al. (1997) reported that low producing cows were at higher risk than their herdmates with average production. High producing cows were less likely to be culled. Another study by Vukasinovic et al. (2001) showed that within each lactation the cows producing less than 80% of the herd average were at 3 to 4 times higher risk than their herdmates with average production. Similar findings were published by Vollema and Groen (1998), Weigel et al. (2003) and Sewalem et al. (2005).

A trend of decreasing risk of culling during years is observed with a decreasing percentage of Holstein breed (Figure 4). It means that crossbred cows with a lower percentage of Holstein genes are less likely to be culled, probably because of better health. On the contrary, the estimations for the effect of Holstein genes in the study by Vollema and Groen (1998) indicated a slightly lower risk of culling for cows with a higher percentage of Holstein genes.

According to Caraviello et al. (2004), the predicted transmitting abilities for longevity of each sire were expressed as the risk of culling his daughters relative to the risk of culling daughters of an average sire. Breeding values for sires expressed as a risk ratio of their daughters were between 0.7 and 1.45. These values are comparable with the values from studies of Vukasinovic (1999) and Schneider et al. (1999).

We used parameters $\rho = 2$ and $\gamma = 4$ in the estimation of sire variance based on analyses by Ducrocq and Sölkner (1998a). The estimated variance for functional LPL (0.0104) was lower than the variances published in the literature (Ducrocq and Sölkner, 1998; Bünger et al., 2001; Sewalem et al., 2005). The calculated heritability in the logarithmic scale was $h^2_{log} = 0.025$, on the original scale it

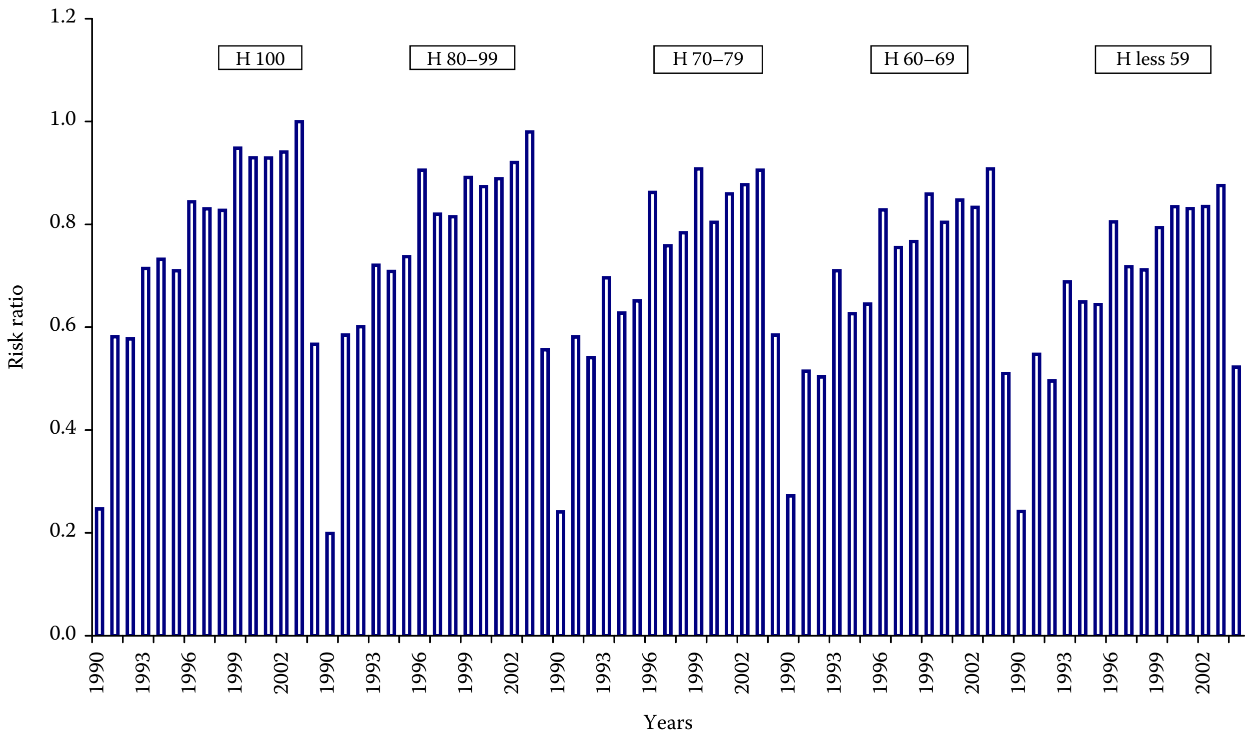

Figure 4. Estimates of the effect of interaction between year and breed

was h^2_{orig} = 0.041. Similar or lower estimates were reported by Schneider et al. (1999), Vollema et al. (2000) and Caraviello et al. (2004) but on the other hand, higher estimated values were published by Bünger (1999), Cruickshank et al. (2002) and Sewalem et al. (2005).

CONCLUSIONS

We can conclude that cows at the beginning of the first lactation and at the end of the first lactation and at the end of any other lactation had the highest risk of culling. Generally, the risk of culling decreased with parity. Cows that were younger at first calving had a lower risk of culling than the older ones. The cows in the class with lowest milk production had a risk of culling that was five times higher than for cows with average milk production. A trend of decreasing risk of culling was observed with a decreasing percentage of Holstein genes. Breeding values for sires expressed as a risk ratio of their daughters were between 0.7 and 1.45. The estimated heritability of functional longevity on the logarithmic scale was for the present data set 0.025 and on the original scale 0.041. The heritability values were in agreement with the values published in literature. The estimated value can be used for the evaluation of breeding values for longevity of cattle in the Czech Republic.

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REFERENCES

Boettcher P.J., Jairath L.K., Dekkers J.C.M. (1999): Comparison of methods for genetic evaluation of sires for survival of their daughters in the first three lactations. J. Dairy Sci., *82*, 1034–1044.

Bünger A. (1999): Die Länge des produktiven Lebens und ihre Beziehung zu linearen Exterieurmerkmalen bei Holstein-Friesian Kühen. [Ph.D. Diss.] Göttingen, Deutschland.

Bünger A., Ducrocq V., Swalve H.H. (2001): Analysis of survival in dairy cows with supplementary data on type scores and housing systems from a region of Northwest Germany. J. Dairy Sci., *84*, 1531–1541.

Caraviello D.Z., Weigel K.A., Gianola D. (2004): Comparison between a Weibull proportional hazards model and linear model for predicting of the genetic merit of US Jersey Sires for daughter longevity. J. Dairy Sci., *87*, 1469–1476.

Cruickshank J., Weigel K.A., Dentine M.R., Kirkpatrick B.W. (2002): Indirect prediction of herd life in Guernsey dairy cattle. J. Dairy Sci., *85*, 1307–1313.

Ducrocq V. (1987): An analysis of length of productive life in dairy cattle. [Ph.D. Diss.] Cornell Univ., Ithaca, NY.

Ducrocq V., Sölkner J. (1998a): Implementation of a routine breeding value evaluation for longevity of dairy cows using survival analysis techniques. In: Proc. 6th World Congr. Genet. Appl. Livest. Prod., *23*, 356–362.

Ducrocq V., Sölkner J. (1998b): "The Survival Kit – V3.0" A package for large analyses of survival data. In: Proc. 6th World Congr. Genet. Appl. Livest. Prod., *27*, 447–448.

Ducrocq V., Quaas R.L., Pollak E.J., Casella G. (1988): Length of productive life of dairy cows. 1. Justification of a Weibull model. J. Dairy Sci., *71*, 3061–3070.

Korsgaard I.R., Andersen A.H., Jensen J. (1999): Discussion of heritability of survival traits. In: Workshop on Genetic Improvement of Functional Traits in Cattle Longevity, May 9–11, Jouy-en-Josas, France.

Nilforooshan M.A., Edriss M.A. (2004): Effect of age at first calving on some productive and longevity traits in Iranian Holstein of the Isfahan province. J. Dairy Sci., *80*, 2130–2135.

Přibyl J., Přibylová J. (2001): Význam jednotlivých laktací pro hodnocení zvířat. Náš chov, *61*, 18–20.

Roxström A., Ducrocq V., Strandberg E. (2003): Survival analysis of longevity in dairy cattle on a lactation basis. Genet. Sel. Evol., *35*, 305–318.

Sewalem A., Kistemaker G.J., Ducrocq V., Van Doormaal B.J. (2005): Genetic analysis of herd life in Canadian dairy cattle on a lactation basis using a Weibull proportional hazards model. J. Dairy Sci., *88*, 368–375.

Schneider M. del P., Monardes H.G., Cue R.I. (1999): Effects of type traits on functional herd life Holstein cows. In: Workshop on Genetic Improvement of Functional Traits in Cattle Longevity, May 9–11, Jouy-en-Josas, France.

Vollema A.R., Groen A.F. (1998): A comparison of breeding value predictors for longevity using a linear model and survival analysis. J. Dairy Sci., *81*, 3315–3320.

Vollema A.R., Van Der Beek S., Harbers A.G.F., De Jong G. (2000): Genetic evaluation for longevity of Dutch dairy bulls. J. Dairy Sci., *83*, 2629–2639.

Vukasinovic N. (1999): Application of survival analysis in breeding for longevity. In: Workshop on Genetic Improvement of Functional Traits in Cattle Longevity, May 9–11, Jouy-en-Josas, France.

Vukasinovic N., Moll J., Künzi N. (1997): Analysis of productive life in Swiss Brown cattle. J. Dairy Sci., *80*, 2572–2579.

Vukasinovic N., Moll J., Künzi N. (1999): Genetic evaluation for length of productive life with censored records. J. Dairy Sci., *82*, 2178–2185.

Vukasinovic N., Moll J., Casanova L. (2001): Implementation of a routine genetic evaluation for longevity based on survival analysis techniques in dairy cattle populations in Switzerland. J. Dairy Sci., *84*, 2073–2080.

Weigel K.A., Palmer R.W., Caraviello D.Z. (2003): Investigation of factors affecting voluntary and involuntary culling in expanding dairy herds in Wisconsin using survival analysis. J. Dairy Sci., *86*, 1482–1486.

Yazdi M.H., Visscher P.M., Ducrocq V., Thompson R. (2002): Heritability, reliability of genetic evaluations and response to selection in proportional hazard models. J. Dairy Sci., *85*, 1563–1577.

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