Iranian Journal of Applied Animal Science

Study of Longevity in Dairy Cattle

Research Article

M. Rakhshani Nejad[1], N. Emamjomeh Kashan[1*], M. Rokouei[2,3], M. Aminafshar[1] and H. Faraji-Arough[4]

[1] Department of Animal Science, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2] Department of Animal Science, Faculty of Agriculture, University of Zabol, Zabol, Iran
[3] Department of Animal and Poultry Science, College of Aburaihan, University of Tehran, Pakdasht, Tehran, Iran
[4] Research Center of Special Domestic Animals, University of Zabol, Zabol, Iran

Received on: 25 Apr 2020
Revised on: 20 Aug 2020
Accepted on: 1 Oct 2020
Online Published on: Sep 2021

*Correspondence E-mail: kashannasser@gmail.com

Online version is available on: www.ijas.ir

ABSTRACT

This study aimed to estimate the effect of environmental factors on variation of the longevity and the genetic parameters of the trait in Holstein dairy cows in Iran. The records of 181738 cows in the years 2001 to 2018 were provided by the Animal Breeding Center of Iran (Karaj, Iran). Profitability in dairy herds depends on animal survival in the herd, which is provided by reducing involuntary culling and increasing the voluntary culling in the herd. The survival was defined as the lifespan, the lifetime milk, fat, and protein yield after first calving, and lifetime days in milk. The effect of environmental factors on traits and risk of culling was estimated using Survival kit and cmprsk statistical packages. The variance components were estimated by Gibbs sampling method based on exponential distribution, incomplete data, and survival analysis. The effects of herd, season, and age of calving on traits were significant (P<0.001). The risk of culling of cows with difficult calving was higher than others. The risk of culling of cows calved in spring was higher than in other seasons. The heritability of different traits of survival estimated to be 0.0067-0.0147. The results showed that the effect of different environmental factors on variation of longevity is significant, and the heritability of the trait is low. However, a review of the literature indicates that, despite the low heritability of the trait, it can be improved in a population through genetic selection. This approach is justified, as longevity is not only important for the farmer from the economic point of view, but it also affects the increase of animal welfare and social acceptance of the dairy sector.

KEY WORDS Gibbs sampling, hazard function, survival heritability.

INTRODUCTION

The natural life span of cattle is reported to be up to 20 years when they would die of old age. In commercial systems, the cow would clave at 2-3 years of age and would be culled at about six years of age (Fetrow *et al.* 2006). The length of productive life is the time from first calving to culling. Culling or departure of animals from the herd is because of sale, slaughter, salvage, or death (Fetrow *et al.* 2006). The age at first calving, the lifespan and the length of productive life affect genetic progress and economic performance of dairy cows (Cielava *et al.* 2017). The results of a research showed that the risk of culling increased with parity (Figure 1). The expected remaining lifetime for cows calving in parities 1 to 6 was 907, 697, 553, 469, 423, and 399 days, respectively (De Vries *et al.* 2010). They reported that the risk of culling in the first two months after calving was increased. The risk of culling at day 5 was lower than the risk of culling at day 30 after calving, except for first lactation cows. This could be related to a greater risk of dystocia in first parity cows. Later in lactation, the risk of culling of cows that were not pregnant was higher.

This risk started to increase later for first parity cows (around day 300) compared to older cows (around day 220). This was likely due to a flatter lactation curve for first parity cows, and therefore these cows had more opportunity to get pregnant. Also, the daily risk of culling for pregnant cows compared to open (non-pregnant) was 3 to 7 times lower.

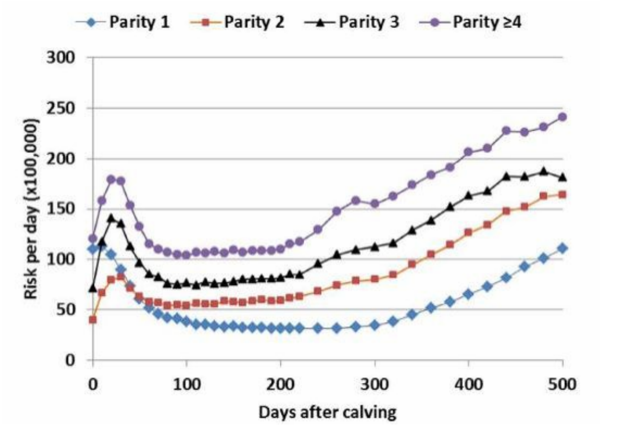

Figure 1 Daily risk of culling by days after calving and parity

Other reproductive factors that were found to affect the increase of the risk of culling were greater calving difficulty (hazard ratio (HR) ≤ 1.95, where HR= 1 is the baseline), and birth to males or twins (HR≤1.36) (De Vries *et al.* 2010).

Similar effects of reproduction factors on culling are reported for Canadian dairy cows (Sewalem *et al.* 2008). Longer open days in parity is associated with increased risk of culling in subsequent calving (Pinedo and De Vries, 2010). They also reported that the risk of death from 14 days before the calculated due date to the first 60 days after calving increased from 2.5% to 5.8% when open days increased from 68 to more than 301 days. Also, the risk of live culling increased from 5 to 8.1 percent, with the same increase in open days.

Early lactation cull risk varies greatly between herds. For instance, in a study in Pennsylvania herds, the cull risk for the first 60 days in milk was 6.8 percent which shows that most of the death occurs in early lactation (Miglior *et al.* 2005).

Livestock survival is an economic feature that has a significant impact on the profitability of livestock production (Lurdes Kern *et al.* 2016). The survival rate of dairy cows in the herd depends on the rate of culling (optional or non-optional) from the herd. Non-voluntary culling of cows is in cases such as reproductive problems, mastitis, lameness, etc. However, voluntary culling is in the case of low milk production and based on the farmer's decision (Van Arendonk, 1985). Therefore, two different definitions are presented for survival (Ducrocq *et al.* 1988):

1) The lifespan, which is the period between birth and removal of an animal from the herd.
2) The length of productive life (LPL), which is the period between the first calving and the time of removal from the herd.

At the time of genetic evaluation of animals for survival trait, the available data may be from animals still alive and are in the herd and the data from animals that are died or culled. The data of live animals do not represent the true lifespan of the animals and are called censored data. The model used for censored data to calculate survival traits is proportional Hazard function and the Weibull model (Ducrocq *et al.* 1988; Vukasinovic *et al.* 2001). The heritability of survival traits using censored data and the Weibull model are reported to be 0.05-0.18 (Forabosco *et al.* 2009). The heritability of survival using linear models, random regression and threshold model are reported to be 0.01 to 0.22 (Sasaki, 2013; Strapakova *et al.* 2014; Imbayarwo-Chikosi *et al.* 2015).

Since the involuntary culling of animals has a negative effect on farm productivity, thus, in different countries, the longevity trait is included in the breeding program and the breeding value for the trait is predicted. The present study was conducted to estimate the effect of environmental factors on variation of longevity and the genetic parameters of the trait in Iranian Holstein population.

MATERIALS AND METHODS

The data of 181738 Holstein cows from the years 2001-2018 provided by the Iranian Animal Breeding Center used for this study (Table 1).

Table 1 Characteristics of the data

Characteristics	Number
Pedigree animals	415073
Animals with records	181738
Number of males	8098
Number of females	277715
Number of inbred animals	340523
with known parents	371170
Animals with progeny	285813
Animals without progeny	129260

The longevity of the animals, defined as the period between birth date and last recording date or culling date and is called lifespan. Also, the total amount of milk (LMY), fat (LFY) and protein (LPY) production during the productive life of the animals calculated, and the number of days in milk that animal had in lifespan (LDIM). The data of animals with the first calving age of 20-40 months were used for calculation of milk production.

The data of animals with known culling date and the animals had passed 18 months from the last milk recording were considered uncensored, and animals without culling date were considered as censored. The Cox relative risk model (1) was used to estimate environmental factors affecting traits:

$$(y \times s)_{ijklm} = \mu + H_i + S_j + Y_k + CE_l + b_1(age)_m + e_{ijklm}$$

Where:

y_{ijklm}: phenotypic observations for traits.
s_{ijklm}: type of culling.
y: overall mean.
H_i: herd effect.
S_j: calving season.
Y_k: year of calving.
CE_l: code of difficult calving.
$b_1(age)_m$: age of calving.
e_{ijklm}: residual effect.

The risk of culling up to 1000 days for *LPL* and up to 20000 kg of milk, 500 kg of fat and protein production were compared for difficult calving, season and year of calving. The probability of survival of animals for different traits were estimated using Survival kit software (Therneau and Lumley, 2014). The exponential distribution of censored survival data was used to calculate genetic parameters using model 2.

$$y = Xb + Za + e$$

Where:

y: observation vector.
X and Z: coefficient matrices for fixed and random effects respectively.
b, a, and e: vectors are associated with fixed effects, random additive, and residuals effects, respectively.

A total of 1000000 samples were produced with a 150000 burn-in period and 150 sampling intervals. The BOA software was used to control the convergence of analyzes by Geweke diagnostic method (Smith, 2007). The Survival (Therneau and Lumley, 2014) and Cmprsk (Fine and Gray, 1999) statistical packages were used to determine the factors affecting traits and to calculate the risk of animal culling and the MCMCglmm statistical package (Hadfield, 2010) was used to estimate variance components.

RESULTS AND DISCUSSION

The log-likelihood, chi-square, degrees of freedom, and probability of the factors affecting survival variables are presented in Table 2. The effect of the herd, year and season of calving, difficult calving and age of calving on the survival variables were significant (P<0.001).

Difficult calving can be a major cause of death of the cows during calving and reduce cow fertility and reproductive efficiency. Difficult calving increases female cow infertility, postpartum diseases, and the involuntary culling of the female cows (Fetrow *et al.* 2006). The impact of difficult calving on the reduction of milk production (Djemali *et al.* 1987) can increase the un-voluntary culling of the cows from the herd. The difference in the risk of culling in different seasons of calving was significant (P<0.01). The average risk of culling up to 1000 days after first calving was higher in cows calving in autumn than in other seasons (Table 3). The relationship between year and season of calving and herd size with lifespan in Polish Simmental cattle (Morek-Kopec and Zarnecki, 2017), Czech Holstein cows (Strapakova *et al.* 2014), Serbian black and white and Simmental cows (Stanojević *et al.* 2016) are reported to be significant. The herd size effect on survival is significant (Chirinos *et al.* 2007). Therefore, considering the effects of herd, year and season of calving and herd size, it is possible to study the risk of culling caused by herd size. Large herd size is an effective factor in the increase of culling risk (Strapakova *et al.* 2014). In a study in Polish Simmental herds, the risk of culling of cows in autumn was higher than in other seasons (Morek-Kopec and Zarnecki, 2017). In the present study, the trend of risk of culling in different survival variables during the years of 1998-2018 is in decreasing (Figure2).

Differences in the rate of culling in different years are examined by considering the year and season of calving in models. Herd management, health, rainfall, disease and nutrition all affect the culling risk in different years (Jovanovac *et al.* 2013).

The mean of *LPL* of uncensored data was 1042 days (34 months), and the mean of LMY, LFY and LPY were 23157.2, 756.5 and 713.4 kg, respectively (Table 4).

The average number of lactation periods of Holstein cows in the US is 2.8 (Tsuruta *et al.* 2005) and in Serbia is 3.04 (Stanojević *et al.* 2016). The average number of months between the first calving and last milk production record for Iranian Holstein cows has been reported to be 30.1 (Nilforooshan and Edriss, 2004).

The components of variance and heritability of different traits are presented in Table 5. Heritability estimates show that the variance of the survival variables is due to environmental and management factors, and their genetic selection response might be low. Therefore, better environmental conditions can be useful to improve survival traits.

Using random regression, and sire model, the heritability of survival for Tunisian cows at different lactation periods was reported between 0.02 and 0.03 (Grayaa *et al.* 2019).

Table 2 Environmental effects on survival trait

Trait	Factors	Log-likelihood	Degrees of freedom	Chi-square	Probability
The length of productive life	Herd	-2009519	624	21176.694	< 0.001
	Year of calving	-2004746	17	9545857	< 0.001
	Season of calving	-2004485	3	522.185	< 0.001
	calving difficulty	-2004416	4	139.513	< 0.001
	Calving age	-1959442	1	89947.475	< 0.001

Table 3 Effect of calving difficulty and season on the risk of culling

Traits		LPL	LMY	LFY	LPY
Factors	Code[1]	Up to 1000 days of age	Up to 20000 kg	Up to 500 kg	Up to 500 kg
Calving difficulty	1	0.474 (0.000003)^{e}	0.386 (0.000002)^{e}	0.280 (0.000002)^{e}	0.296 (0.000002)^{e}
	2	0.530 (0.00002)^{b}	0.418(0.000002)^{d}	0.301 (0.000001)^{d}	0.325 (0.000002)^{d}
	3	0.513 (0.00003)^{d}	0.429 (0.000003)^{c}	0.310 (0.00003)^{c}	0.330 (0.000003)^{c}
	4	0.517 (0.00018)^{c}	0.473 (0.000002)^{b}	0.341 (0.00017)^{b}	0.373 (0.00017)^{b}
	5	0.546 (0.00163)^{a}	0.491 (0.00159)^{a}	0.383 (0.00150)^{a}	0.417 (0.00154)^{a}
Season of calving	1	0.530 (0.000010)^{b}	0.440 (0.000009)^{a}	0.320 (0.000008)^{a}	0.338 (0.000008)^{a}
	2	0.465 (0.000007)^{d}	0.376 (0.000007)^{c}	0.268 (0.000006)^{c}	0.284 (0.000006)^{c}
	3	0.545 (0.000007)^{a}	0.364 (0.000007)^{d}	0.263 (0.000006)^{d}	0.282 (0.000006)^{d}
	4	0.501 (0.000008)^{c}	0.407 (0.000008)^{b}	0.301 (0.000007)^{b}	0.316 (0.000007)^{b}

[1] Code for factor calving difficulty 1: no help; 2: with the help and no harm; 3: with the help and low damage; 4: with much help and damage and 5: difficult calving and cesarean. Code for factor season of calving 1: spring; 2: summer; 3: fall and 4: winter.
LPL: length of productive life; LMY: total amount of milk; LFY: total amount of fat and LPY: total amount of protein.

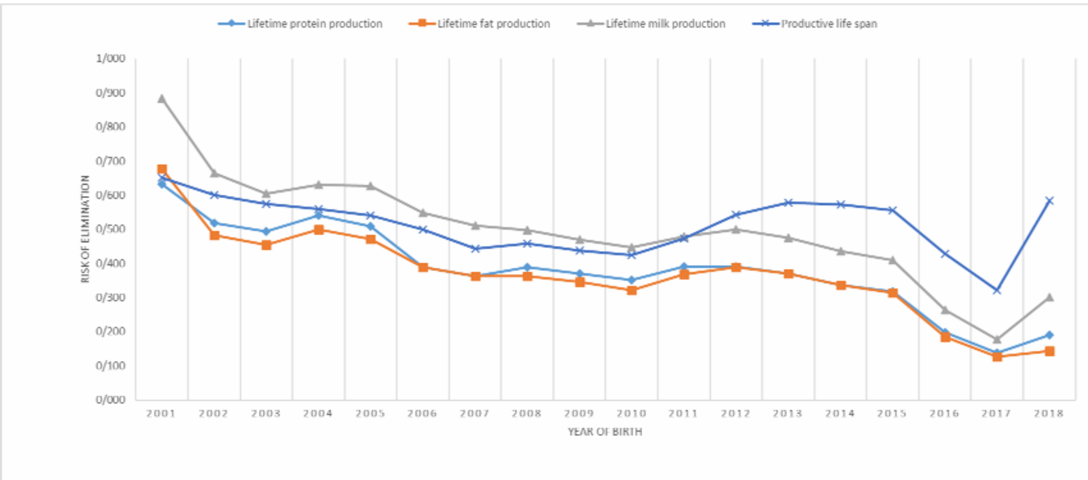

Figure 2 The trend of risk of culling in different years

Table 4 Mean of different survival variables for uncensored and censored data

Traits	Data type	Average	Standard Deviation	Minimum	Maximum
LPL (day)	Uncensored	1042	733.9	59	7113
	Censored	511.4	417.5	61	4792
LMY (kg)	Uncensored	23157.2	16750.3	214.5	158437
	Censored	15324.2	12289.6	452.6	136580
LFY (kg)	Uncensored	756.5	563.02	5.9	5326.4
	Censored	494.5	403.6	9.8	4757.5
LPY (kg)	Uncensored	713.4	514.8	6.8	5255.9
	Censored	467.7	380.1	11.3	4043.1

LPL: length of productive life; LMY: total amount of milk; LFY: total amount of fat and LPY: total amount of protein.

Using the relative Weibull hazard model, the heritability of lifespan for Tunisian and Czech cows estimated in the range of 0.03 to 0.181 (Zavadilova and Stipkova, 2012).

The heritability for the survival of Simmental cows using the animal, sire, and Weibull model was reported to be 0.056, 0.037, and 0.075, respectively (Raguz *et al.* 2014). The factors can affect a cow to be culled from a dairy farm include her level of milk production, whether she gets pregnant, and if she stays healthy and free from disease and illness. When a cow is culled from a farm, she is usually sold to slaughter for beef. Therefore, the main factor which affects the dairy producer to cull the animal is the financial and economics of farming. This means the improvement of the longevity of dairy cows through genetic selection is a practical choice to help the income of the farmer. Prediction and publication of breeding value for longevity for dairy cows have been started since 1999 in some countries such as the Netherlands and have become very important due to the inclusion of the breeding values in the national selection index (Meuwissen *et al.* 2001).

In the Netherlands, the genetic progress for longevity over time has been positive for three breeds (Figure 3). In the beginning, the weight of the breeding value for longevity was 33 percent. Then the weight has gradually decreased from 33 to 11 percent in the current national index. It is because of more health and fertility, and breeding values became available and were included in the national index. At present, prediction of breeding value for longevity is perceived as an important value for bulls.

The progress between the years 1990 and 2010 is about 21, 18, and 12 breeding value units for RDC, Holstein and Jersey, respectively. One unit corresponds to about seven days longer life regardless of the breed, so the genetic capacity during this period has improved with about 5, 4, and 3 months for RDC, Holstein and Jersey, respectively. These values show that it is expected the cows born in 2010 to produce some months longer than cows born in 1990. This example shows that despite low values of heritability reported for longevity, it is possible to improve the genetic potential of the animals for the trait.

Table 5 The variance component and heritability of survival traits

Traits	Factors	Average	Standard deviation	Minimum	Maximum
LPL	σ_a^2	0.0034	0.0003	0.0027	0.0040
	σ_e^2	0.2602	0.0018	0.2565	0.2637
	σ_p^2	0.2636	0.0018	0.2597	0.2670
	h^2	0.0127	0.0013	0.0103	0.0153
LMY	σ_a^2	0.0023	0.0002	0.0019	0.0027
	σ_e^2	0.3408	0.0012	0.3385	0.3431
	σ_p^2	0.3431	0.0012	0.3406	0.3455
	h^2	0.0067	0.0005	0.0057	0.0078
LFY	σ_a^2	0.0037	0.0004	0.0030	0.0044
	σ_e^2	0.2630	0.0022	0.2586	0.2674
	σ_p^2	0.2667	0.0023	0.2622	0.2712
	h^2	0.0139	0.0014	0.1134	0.0167
LPY	σ_a^2	0.0036	0.0004	0.0029	0.0043
	σ_e^2	0.2601	0.0018	0.2565	0.2634
	σ_p^2	0.2637	0.0018	0.2603	0.2673
	h^2	0.0137	0.0014	0.0110	0.0164

LPL: length of productive life; LMY: total amount of milk; LFY: total amount of fat and LPY: total amount of protein.
σ_a^2: additive genetic variance; σ_e^2: residual variance; σ_p^2: phenotypic variance and h^2: heritability.

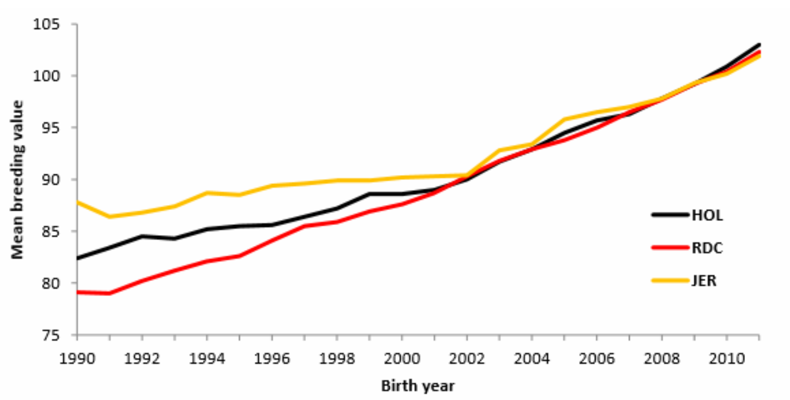

Figure 3 Genetic progress for the longevity of Nordic dairy cows

CONCLUSION

Finally, the statistics show that every year the dairy farmers in Iran inseminate the cows with frozen semen, which are mostly imported from abroad. One practical approach to improve longevity is to use the semen of bulls with good longevity of their daughters. Also, it is recommended that the Animal Breeding Center of Iran include the trait of longevity in the national selection index of the bulls.

ACKNOWLEDGEMENT

The authors appreciate the co-operation of the Animal Breeding Center (Karaj, Iran) for providing the data used in this study.

REFERENCES

Chirinos Z., Carabano M.J. and Hernández D. (2007). Genetic evaluation of length of productive life in the Spanish Holstein-Friesian population: Model validation and genetic estimation. *Livest. Sci*. **106,** 120-131.

Cielava L., Jonkus D. and Paura L. (2017). The effect of cow reproductive traits on lifetime productivity and longevity. *Int. J. Biol. Biomol. Agric. Food Biotechnol. Eng*. **11,** 220-223.

De Vries A., Olson JD and Pinedo PJ. (2010). Reproductive risk factors for culling and productive life in large dairy herds in the eastern United States between 2001 and 2006. *J. Dairy Sci*. **93,** 613-623.

Djemali M., Berger P.J. and Freeman A.E. (1987). Ordered categorical sire evaluation for dystocia in Holsteins. *J. Dairy. Sci.* **70,** 2374-2384.

Ducrocq V.P., Quaas R.L., Pollak E.J. and Casella G. (1988). Length of productive life of dairy cows. 2. Variance component estimation and sire evaluation. *J. Dairy Sci.* **71,** 3071-3080.

Fetrow J., Nordlund K.V. and Norman H.D. (2006). Invited review: culling: nomenclature, definitions, and recommendations. *J. Dairy. Sci*. **89,** 1896-1905.

Fine J.P. and Gray R.J. (1999). A proportional hazards model for the subdistribution of a competing risk. *J. Am. Stat. Assoc*. **94,** 496-509.

Forabosco F., Jakobsen J.H. and Fikse W.F. (2009). International genetic evaluation for direct longevity in dairy bulls. *J. Dairy Sci.* **92,** 2338-2347.

Grayaa M., Vanderick S., Boulbaba Rekik B., Ben Gara A., Hanzen C., Grayaa1 S., Reis Mota R., Hammami H. and Gengler N. (2019). Linking first lactation survival to milk yield and components and lactation persistency in Tunisian Holstein cows. *Arch. Anim. Breed*. **62,** 153-160.

Hadfield J.D. (2010). MCMC methods for multi-response generalized linear mixed models: The MCMCglmm R package. *J. Stat. Softw*. **33,** 1-22.

Imbayarwo-Chikosi V.E., Dzama K., Halimani T.E., Van Wyk J.B., Maiwashe A.N. and Banga C.B. (2015). Genetic prediction models and heritability estimates for functional longevity in dairy cattle. *South African J. Anim. Sci*. **45,** 105-121.

Jovanovac S., Raguz N., Solkner J. and Meszaros G. (2013). Genetic evaluation for longevity of Croatian Simmental bulls using a piecewise Weibull model. *Arch. Tierz*. **56,** 89-101.

Lurdes Kern E., Araujo Cobuci J., Napolis Costa C. and Vincent Ducrocq V. (2016). Survival analysis of productive life in Brazilian holstein using a piecewise Weibull proportional hazard model. *Livest. Sci*. **185,** 89-96.

Miglior F., Muir B.L. and Van Doormaal B.J. (2005). Selection indices in Holstein cattle of various countries. *J. Dairy Sci*. **88,** 1255-1263.

Meuwissen T.H.E., Hayes B.J. and Goddard M.E. (2001). Prediction of total genetic value using genome-wide dense marker maps. *Genetics*. **157,** 1819-1829.

Morek-Kopec M. and Zarnecki A. (2017). Genetic evaluation for functional longevity in Polish Simmental cattle. *Czech J. Anim. Sci.* **62(7),** 276-286.

Nilforooshan M.A. and Edriss M.A. (2004). Effect of age at first calving on some productive and longevity traits in Iranian Holsteins of the Isfahan province. *J. Dairy Sci*. **87,** 2130-2135.

Pinedo P.J., De Vries A. and Webb D.W. (2010). Dynamics of culling risk with disposal codes reported by Dairy Herd Improvement dairy herds. *J. Dairy Sci*. **93,** 2250-2261.

Raguz N., Jovanovac S., Meszaros G. and Solkner J. (2014). Linear *vs*. piecewise Weibull model for genetic evaluation of sires for longevity in Simmental cattle. *Mljekarstvo*. **64,** 141-149.

Sasaki O. (2013). Estimation of genetic parameters for longevity traits in dairy cattle: A review with focus on the characteristics of analytical models. *Anim. Sci. J*. **84,** 449-460.

Sewalem A., Miglior F., Kistemaker G.J., Sullivan P. and Van Doormaal B.J. (2008). Relationship between reproduction traits and functional longevity in Canadian dairy cattle. *J. Dairy Sci*. **91,** 1660-1668.

Smith B.J. (2007). Boa: an R package for MCMC output convergence assessment and posterior inference. *J. Stat. Soft.* **21,** 1-37.

Stanojević D., Đedović1 R., Bogdanović1 V., RagUž N., Popovac1 M., Janković D. and Štrbac L. (2016). Evaluation of the heritability coefficients of longevity in the population of Black and White cows in Serbia. *Mljekarstvo*. **66,** 322-329.

Strapakova E., Candrak J., Strapak P. and Trakovicka A. (2014). Genetic evaluation of the functional productive life in Slovak Simmental cattle. *Arch. Tierz*. **56,** 797-807.

Therneau T.M. and Lumley T. (2014). Package 'survival'. WebMD. https://tbrieder.org/epidata/course_reading/e_therneau.pdf. Accessed Feb. 2020.

Tsuruta S., Misztal I. and Lawlor T.J. (2005). Changing definition of productive life in US Holsteins: Effect on genetic correlations. *J. Dairy Sci*. **88,** 1156-1165.

Van Arendonk J.A.M. (1985). Studies on the replacement policies in dairy cattle. II. Optimum policy and influence of changes in production and prices. *Livest. Prod. Sci.* **13,** 101-112.

Vukasinovic N., Moll J. and 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.

Zavadilova L. and Stipkova M. (2012). Genetic correlations between longevity and conformation traits in the Czech Holstein population. *Czech J. Anim. Sci*. **57,** 125-136.