Biotechnology in Animal Husbandry 35 (3), 229-242 , 2019
Publisher: Institute for Animal Husbandry, Belgrade-Zemun

ISSN 1450-9156
UDC 636.031'636.2
https://doi.org/10.2298/BAH1903229P

EFFECT OF NON-GENETIC FACTORS ON LONGEVITY TRAITS IN SIMMENTAL COWS

Milun Petrović[1], Simeon Rakonjac[1], Vladan Bogdanović[2], Snežana Bogosavljević-Bošković[1], Radojica Đoković[1], Radica Đedović[2], Miloš Petrović[1]

[1]University of Kragujevac, Faculty of Agronomy Čačak, Cara Dušana 34, Čačak, Republic of Serbia
[2]Univesity of Belgrade, Faculty of Agriculture, Nemanjina 6, 11080 Belgrade, Republic of Serbia
Corresponding author: Milun Petrović, milunp@kg.ac.rs
Original scientific paper

Abstract. The effects of fixed non-genetic factors (farm, season of birth, year of birth, total number of lactations) and a continuous non-genetic factor (age at first conception) on the expression and variability of longevity traits such as age at culling, length of productive life, days in milk and cow efficiency index were investigated in 2548 Simmental cows in three farming areas. Based on the model used for the analysis of the effects of non-genetic factors, including the environment and cow age at first conception, on the expression and variability of longevity traits, the overall means for age at culling, length of productive life, days in milk and cow efficiency index were 2445.21±17.49 days, 1562.55±17.71 days, 1094.17±12.28 days and 58.68±0.32%, respectively. The effect of farming area, year of birth and lactation group on longevity traits was very significant ($P<0.01$), whereas the effect of season of birth was significant ($P<0.05$). Age at first conception had a highly significant ($P<0.01$) effect on age at culling, length of productive life and cow efficiency index, and no significant effect on days in milk ($P>0.05$). Based on the model used, the coefficients of determination (R^2) were very significant ($P<0.01$) for all longevity traits, and ranged from 0.898 for age at culling to 0.959 for days in milk.

Key words: longevity, fixed effects, continuous effects, Simmental cows.

Introduction

Research into phenotypic and genetic variability of production traits has an immense practical importance as this variability underlies annual and generational selection effects.

Selection work in dairy herds in the last 50 years has strongly focused on milk performance traits. This directselection based on milk performance traits has led to deterioration of fertility, longevity and immunity traits, which have a critical role in profitable milk production. As reported by the United States Department of Agriculture, until 1994, the official selection index used in the selection of dairy cattle included only milk performance traits in calculating the aggregate genotype *(Van Raden, 2004).*

In the last decade of the 20th century and the first decade of the 21st century, many studies *(Allaire and Gibson, 1992; Dekkers, 1993; Smith et al., 2000; Harder et al., 2006; Orpin and Esslemont, 2010)* showed a negative effect of a high level of involuntary cullings of animals from the herd on the economic efficiency of milk production on farms. Longevity as a function of animal's constitution and resistance to diseases, along with high productivity and good composition of milk, is an important trait for the economic efficiency of milk production (*Pogačar et al., 1998)*. Consistently with the results of these studies and to solve problems regarding involuntarycullings, a large number of countries have included functional traits in their models for evaluating the breeding value of animals *(Sewalem et al., 2008).*This approach has led to breeding programmes which have adopted a more balanced approach, with the selection focus moved from milk performance traits to functional traits *(Miglior et al., 2005).* In terms of milk production, functional traits have today become crucial in defining modern breeding programmes aimed at obtaining productive cost-efficient animals. Their basic effect on the economic efficiency of milk production is not achieved through direct increase in animal productivity, but is evidencedby production cost reduction through animal health, resistance, vitality and ability to last a number of lactations *(Bogdanović et al., 2012).*

From its earliest beginnings, research on longevity traits has faced difficulties with both their proper interpretation and understanding the processes which affect them. The main problem in the analysis of longevity traits is that the exact value for this group of traits can be obtained only after the animal has been culled, due to which the generational interval is considerably prolonged and the selection effect reduced. In addition, functional traits often have low variability (occurrence of mastitis, calving ease, diseases of some organs, etc.), which significantly complicates their analysis and proper interpretation of results. As reported by *Fuerst and Sölkner (1997),* many studies have shown that the true productive lifespan cannot be used as an indicator of cow's biological capacity. Therefore, careful attention has been given to functional longevity (yield adjustment) as a better trait to be used in routine genetic evaluation. In Austria, the breeding value of the functional length of productive life has been routinely evaluated since June 1995. These programmes are based on the Cox proportional hazards model.

Longevity and lifetime milk production are significantly affected by a number of non-genetic factors, either discontinuous i.e. fixed (farming area, season of birth, year of birth, season of calving, year of calving, total number of lactations and their interactions) or continuous i.e. non-categorical factors (age at first conception or age at first calving). In many herds, major reasons for culling include low milk production (30–35%), impaired physiological functions (30–40%) andudder diseases (10–15%). Low production is the main culling reason for cows after the first or second lactation, whereas older cows are commonly culled for infertility.

Cattle breeding practices generally involve the use of linear methods and models combining fixed parameters (year, farm, season, lactation) and random variables (age at first conception or age at first calving, genetic effect of father, genetic effect of an individual animal, etc.), which can be either mutually dependent (related) or independent, depending on the trait analysed, with or without interactions. The model selected is essentially the breeding value of the individual *(Bogdanović et al., 2003).*

The objective of the present research was to contribute to a better understanding of variability of longevity traits in Simmental cattle in Serbia caused by different non-genetic effects. This research can serve as the basis of initial endeavours in including this group of traits in the breeding programme for Simmental cattle in Serbia, as well as in evaluating the breeding value of bulls for these traits.

Material and methods

The effect of non-genetic factors on the phenotypic expression and variability of longevity traits was analysed in 2548 Simmental cows born from 1995 to 2008, which were housed in three farming areas:

1. Zlatiborski Suvati (Mt. Zlatibor Pastures) Dairy Cow Farm on Mt. Zlatibor (n=502), loose housing system,
2. dairy cow farm at the Dobričevo farm in Ćuprija (n=956), tie-stall housing system, and
3. private dairy cow farms in the region of Kotraža (n=1090), tie-stall housing system.

The distribution of data on cows across classes of major non-genetic effects is presented in Table 1.

Table 1. Distribution of data across classes of major non-genetic effects

Farm	No. of cows	Season of birth	No. of cows	Year of birth	No. of cows	Total no. of lactations	No. of cows
I (Zlatibor)	502	I	589	1995	164	1	396
		II	727	1996	129	2	512
II (Dobričevo)	956	III	570	1997	184	3	466
		IV	662	1998	169	4	385
III (Kotraža)	1090			1999	246	5	314
				2000	250	6	217
				2001	192	7	143
				2002	213	8	81
				2003	187	9	23
				2004	167	10	11
				2005	172		
				2006	106		
				2007	168		
				2008	201		

Based on the data obtained from birth records of cows housed in three farming areas, the following longevity traits were analysed:

- age at culling (days),
- length of productive life (days),
- days in milk,
- cow efficiency index (%).

Preparation of data for statistical analysis

Longevity traits were calculated using data obtained from birth records of cows, as follows:

Age at culling – by summing up the length of productive life in days and age at first calving.

Length of productive life – by subtracting age at first calving in days from age at culling.

Days in milk – by summing up the lengths of all full lactations during the cow's lifetime i.e. productive life.
Cow efficiency index (%) as a relative measure of longevity, calculated by dividing the length of productive life by cow's age at culling, and multiplying by 100.

Non-genetic effect of the environment

The effect of the following non-genetic factors on lifetime production traits was analysed:

Farming area (farm): The research was conducted at three farming locations, two in the uplands (dairy cow farm on Mt. Zlatibor, which employed loose housing system, and private farms, which used tie-stall housing systems, in Kotraža) and a farm at Dobričevo in the low lands, which employed tie-stall housing system.

Season of birth:

I – spring season (March, April, May),
II – summer season (June, July, August),
III – autumn season (September, October, November),
IV – winter season (December, January, February).

Year of birth: cows born from 1995 to 2008.

Total number of lactations: 1–10.

Age at first conception.

Evaluation of non-genetic effects of the environment

The effect of non-genetic environment-related factors on longevity traits (arithmetic means (X), standard errors of arithmetic means (Sx), significance of the effect of non-genetic factors and coefficients of determination (R^2)) was analysed using the general linear model of the *Statistica 6.0* statistical software. This procedure ensures a simultaneous analysis of a number of different effects, either categorical factors (farming area, total number of lactations, season of birth and year of birth) or continuous factors (age at first conception).

The analysis of the effect of some non-genetic factors on lifetime production traits was performed by the following model:

$$y_{ijkl} = \mu + FR_i + SB_j + YB_k + L_l + b_1(x_1 - \bar{x}_1) + e_{ijkl}\text{ , where:}$$

y_{ijkl} – individual of the i-th farming area, j-th season of birth, k-th year of birth and l-th total number of lactations,

μ – general mean value of population when all classes of effects (FR, SB, YB, L) are equally present

FR_i – fixed effect of the i-th farming area(1–3),

SB_j – fixed effect of the j-th season of birth (1–4),

YB_k – fixed effect of the k-th year of birth (1–14),

L_l – fixed effect of the l-th total number of lactations (1–10),

b_1 – linear regression coefficient of the effect of age at first conception, and

e_{ijkl} – other non-determined effects.

Further analysis of longevity traits presents coefficients of determination (R^2) for each trait analysed, which are proportions of residual variance i.e. variance of the model divided by 100.

Results and discussion

The results of the analysis of the effect of non-genetic environment-related factors on longevity traits (cow's age at culling, length of productive life, days in milk and cow efficiency index) are presented in Table 2. Depending on the effect of non-genetic factors (farming area, season of birth, year of birth, total number of lactations and cow's age at first conception), the table presents arithmetic means and standard errors of arithmetic means (X±Sx),the significance of the effect of non-genetic factors and coefficients of determination (R^2) for all longevity traits analysed.

Table 2. Arithmetic means (X), standard errors of arithmetic means (Sx), significance of the effect of non-genetic factors and coefficients of determination (R^2) for longevity traits

Non-genetic effects	n	Age at culling (days) $\bar{X}\pm S_{\bar{x}}$	Length of productive life, (days) $\bar{X}\pm S_{\bar{x}}$	Days in milk $\bar{X}\pm S_{\bar{x}}$	Cow efficiency index, % $\bar{X}\pm S_{\bar{x}}$
Mean - μ	2548	2445.21±17.49	1562.55±17.71	1094.17±12.28	58.68±0.32
Farming area (A)					
Zlatibor	502	2495.51±36.10^{a}	1601.12±36.86^{a}	1246.08±29.99^{a}	59.99±0.64^{a}
Dobričevo	956	2373.89±25.40^{b}	1500.59±25.93^{b}	1000.49±18.06^{c}	58.70±0.49^{b}
Kotraža	1090	2484.59±29.89^{a}	1599.14±30.07^{a}	1106.36±19.13^{b}	58.05±0.55^{c}
Season of birth (B)					
Spring (1)	589	2433.46±36.47^{b}	1557.60±36.82^{b}	1101.11±25.89^{b}	58.70±0.68^{b}
Summer (2)	727	2516.28±34.09^{a}	1627.19±34.39^{a}	1126.31±22.50^{a}	59.49±0.60^{a}
Autumn (3)	570	2345.59±35.24^{c}	1468.69±35.90^{c}	1025.15±24.89^{c}	57.31±0.69^{c}
Winter (4)	662	2463.37±33.76^{b}	1576.81±34.29^{b}	1112.11±25.05^{ab}	58.95±0.63^{b}
Year of birth (C)					
1995	164	3081.19±64.50^{a}	2220.41±64.75^{a}	1593.35±46.95^{a}	69.67±0.81^{a}
1996	129	2736.03±67.75^{bc}	1866.03±68.84^{bc}	1365.29±50.57^{b}	65.23±1.06^{b}
1997	184	2315.73±55.90^{e}	1434.43±56.77^{f}	1048.67±43.28^{f}	57.50±1.13^{e}
1998	169	2234.38±67.95^{f}	1359.22±67.51^{g}	989.55±46.23^{g}	54.68±1.36^{f}
1999	246	2337.93±52.02^{e}	1452.05±52.35^{f}	1071.16±38.29^{f}	57.43±0.98^{e}
2000	250	2226.55±56.84^{f}	1346.46±58.08^{g}	989.04±41.66^{g}	54.29±1.11^{fg}
2001	192	2683.18±75.36^{c}	1822.41±75.10^{c}	1243.71±48.64^{c}	62.31±1.19^{c}
2002	213	2559.71±77.88^{d}	1724.62±76.47^{d}	1183.60±49.82^{d}	59.82±1.29^{d}
2003	187	2770.21±66.77^{b}	1891.78±65.94^{b}	1222.17±43.55^{c}	64.61±0.91^{b}
2004	167	2544.93±60.93^{d}	1672.02±61.51^{d}	1135.57±41.50^{e}	61.86±1.06^{c}
2005	172	2516.76±56.36^{d}	1602.60±59.92^{e}	1110.46±43.26^{e}	59.46±1.18^{d}
2006	106	2220.41±66.91^{f}	1298.53±68.44^{gh}	864.29±43.63^{h}	53.88±1.56f^{f}
2007	168	2183.40±41.74^{f}	1240.21±43.90^{h}	805.98±31.17^{i}	53.51±1.13^{g}
2008	201	1980.93±40.79^{g}	1080.47±42.37^{i}	758.44±29.18^{j}	50.25±1.15^{h}
Total number of lactations (D)					
1	396	1328.37±10.66^{j}	413.82±8.64^{j}	312.15±3.82^{j}	30.43±0.40^{i}
2	512	1774.40±12.86^{i}	875.86±11.66^{i}	619.45±5.23^{i}	48.69±0.29^{h}
3	466	2225.93±15.44^{h}	1343.13±14.48^{h}	917.19±6.65^{h}	59.90±0.23^{g}
4	385	2668.70±17.73^{g}	1789.88±16.67^{g}	1206.49±8.42^{g}	66.76±0.22^{f}
5	314	3044.55±18.98^{f}	2170.70±17.21^{f}	1515.83±10.02^{f}	71.13±0.19^{e}
6	217	3414.48±23.15^{e}	2563.61±21.46^{e}	1813.07±13.90^{e}	74.95±0.19^{d}
7	143	3788.22±27.82^{d}	2947.81±26.42^{d}	2081.24±17.27^{d}	77.72±0.21^{c}
8	81	4138.84±38.22^{c}	3284.18±35.67^{c}	2361.94±21.66^{c}	79.28±0.24^{b}
9	23	4450.74±70.70^{b}	3621.13±66.82^{b}	2758.56±37.29^{b}	81.31±0.42^{ab}
10	11	4987.18±118.48^{a}	4120.82±119.47^{a}	3042.646±5.04^{a}	82.55±0.73^{a}
Age at first conception (E)					
$b_{xy}\pm S_b$		0.992±0.002**	-0.993±0.002**	0.000±0.002^{ns}	0.009±0.056^{ns}
Anova	**df**				
A	2	**	**	**	**
B	3	*	*	*	*
C	13	**	**	**	**
D	9	**	**	**	**
E		**	**	ns	**
Coefficient of determination – R^2		0.898**	0.901**	0.951**	0.919**

Mean values followed by the same letters across columns are not different (P>0.05) according to LSD test

F-test (Anova) and t-test (coefficient of linear regression –b_{xy}): N.S. – P > 0.05; * –P < 0.05; ** – P < 0.01;

The average age at culling and length of productive life in all tested cows were 2445.21±17.49 and 1562.55±17.71 days, respectively. The total number of days in milk was 1094.17±12.28, and cow efficiency index was 58.68±0.32%.

Farming area or farm commonly has a significant effect on longevity traits due to housing system, nutrition, animal care, climate, age structure, herd size and other factors associated with farm operation and management practices. The interaction of these factors is characteristic of each farm. Hence, there are differences across herds and farms even when the genetic potential for milk production is similar. The effect of farming area on all longevity traits in this research was very significant (P<0.01). The highest expression of these traits was observed at the farm on Mt. Zlatibor as the result of loose housing system and grazing during the summer season, whereas their lowest values were recorded for cows at the Dobričevo farm, which employed tie-stall housing without grazing. The values of these traits in cows in the Kotraža region were higher than Dobričevo cows, as the result of more relaxed farming conditions, including a small number of animals and more extensive farming, which favoured the longevity traits analysed.

The effect of season of birth on longevity traits in cows is the result of changes in climate, primarily temperature and precipitation, leading to changes in housing system (barn-based and pasture-based) and cow health as major factors determining the expression of these traits. Longevity traits were significantly affected by season of birth (P<0.05). The highest values were recorded for cows born in the summer season, and the lowest for cows born in autumn. The most possible reason lies in the fact that calves born in the summer season were initially raised in pastures, as opposed to calves born in autumn which were raised in poorer barn-based conditions immediately after calving, which adversely affected their immunity and health in general, as well as the expression of longevity traits.

The effect of year of birth on the expression of longevity traits is evidenced through climate conditions across production years and feed quality and quantity. Moreover, farming technology and health management have been improving over the years, and there has been more or less annual selection success. Year of birth in the present experiment had a very significant (P<0.01) effect on longevity traits (age at culling, length of productive life, days in milk and cow efficiency index). Despite improvement in farming technology and health management, longevity traits across years of birth in this research exhibited a decreasing trend. This was associated with increased selection criteria and intensified production, which directly affected the relationship between planned and unplanned cullings and, hence, the expression of longevity traits and milk production profitability. Most cows are culled from production for undesirable reasons, which can be up to 2.5 times more common than planned culling reasons *(Pinedo et al., 2010).* Major causes of involuntary culling include reproductive disorders, mastitis, hoof and leg diseases and injuries *(Nienartowicz-Zdrojewska et al., 2009; Pinedo et al., 2010; Chiumia, 2011; Ansari-Lari et al., 2012; Stojić et al., 2012)*.

The effect of total number of lactations on longevity traits was very significant (P<0.01). The increase in lactation numbers directly and indirectly led to an increase in longevity traits. The same finding was reported by *Petrović D.M. et al., (2004).* In 143 Simmental cows housed at the Zlatiborski Suvati (Zlatibor Pastures) farm, the author used the general linear model procedure and determined a very highly significant (P<0.001) effect of total number of lactations on longevity traits such as age at culling, length of productive life, days in milk, and cow efficiency index. The analysis of the effect of lactation number on culling reasons showed that dominant culling reasons varied with lactation. Dominant reasons for culling of first-calversare selection issues (primarily low production) and reproduction problems (*Seegers et al., 1998; Stojić et al., 2012*). First-calvers account for 20–35% of the total number of animals culled per year (*Maher et al., 2008; Pinedo et al., 2010; Chiumia, 2011*). First-calvers that become pregnant late for the first time and those that have less expressed standard characteristics are culled earlier due to the higher risk of low production *(Dürr, 1997).*

Age at first conception had a highly significant effect (P<0.01) on age at culling and length of productive life. The coefficient of linear regression was b_{xy}=0.992 for the first trait, and negative b_{xy}=-0.993 for the second trait. Age at first conception had no significant effect (P>0.05) on days in milk and cow efficiency index.

The effect of age at first conception or age at first calving on longevity traits was examined in a number of studies. In their research on the regression effect of non-genetic factors on longevity traits in Simmental cows, *Petrović D.M.*

et al., (2004; 2008), found a highly significant ($P<0.001$) effect of age at first conception on age at culling and cow efficiency index (b_{xy}=1.386 andb_{xy}=-0.020), whereas their effect on length of productive life and days in milk was non-significant ($P>0.05$). Considerable research has documented that the risk of culling increases (i.e. animals are culled earlier) with increasing age at first calving (*M'hamdi et al., 2010; Raguž, 2012; Zavadilová and Štípková, 2013*). When evaluating the effect of age at first calving on functional longevity in Hostein cows in Tunisia, M'hamdi *et al., (2010)* found that culling risk increased linearly with increasing age at first calving. Specifically, age at first calving of 27 months was set as basal age, with the risk set to 1 for this age. In animals that calved at an average age of 21 months, the risk was 0.96, whereas the risk for the calving age of 39 months was significantly hither – 1.43.

Coefficients of determination, which indicate the degree of explanation of variations of longevity traits by the model employed, were very high, above 0.9 i.e. over 90% of variability in longevity traits was induced by the effect ofnon-genetic environment-related factors and age at first conception. Such high coefficients of determination for longevity traits were mostly due to total number of lactations. The lowest coefficient of determination 0.898 (89.8%) was obtained for age at culling, and the highest 0.951 (95.1%) for days in milk. Somewhat lower coefficients of determination for longevity traits, due to fewer non-genetic factors analysed, were reported by *Petrović D.M. et al., (2004).* In their study on the effect of lactation number and season of calving as fixed non-genetic factors and age at first conception as a continuous factor on longevity traits in 143 Simmental cows, the coefficients of determination ranged from 0.823 for cow efficiency index to 0.894 for days in milk.

Conclusion

Based on the model for analysing the effect of non-genetic environment-related factors and age at first conception on the expression and variability of longevity traits, the following conclusions are drawn:

The general mean values for age at culling, length of productive life, days in milk and cow efficiency index in 2548 tested cows were 2445.21±17.49 days, 1562.55±17.71 days, 1094.17±12.28 days and58.68±0.32%, respectively.

The effect of farming area, year of birth and lactation group on longevity traits was very significant (P<0.01), whereas the effect of season of birth was significant (P<0.05).

Age at first conception as a continuous factor had a highly significant (P<0.01) effect on age at culling, length of productive life and cow efficiency index, and no significant effect on days in milk (P>0.05).

The coefficients of determination (R^2), obtained by the model, were very significant (P<0.01) for all longevity traits and ranged from 0.898 for age at culling to 0.959 for days in milk.

Given that non-genetic factors, both fixed and continuous, had a generally highly significant effect on longevity traits, and were largely responsible for their variations, they should necessarily be included in models for evaluating the breeding value of dairy cows i.e. these traits should be corrected for the effect of these non-genetic factors.

Uticaj sistematskih faktora na osobine dugovečnosti kod krava simentalske rase

Milun Petrović, Simeon Rakonjac, Vladan Bogdanović, Snežana Bogosavljević-Bošković, Radojica Đoković, Radica Đedović, Miloš Petrović

Rezime

Uticaj fiksnih (farma, sezona i godina rođenja, ukupan broj laktacija) i kontinuelnih (uzrast pri prvoj oplodnji) sistematskih faktora na ispoljenost i varijabilnost osobina dugovečnosti kao što su uzrast pri izlučenju, dužina produktivnog života, ukupan broj muznih dana i indeks iskorišćavanja krava proučavan je na uzorku od 2548 simentalskih krava raspoređenih na tri odgajivačka područja. Na osnovu primenjenog modela za analizu uticaja sistematskih faktora okoline i uzrasta krava pri prvoj oplodnji na ispoljenost i varijabilnost osobina dugovečnosti opšti prosek za uzrast pri izlučenju, dužinu produktivnog života, ukupan broj muznih dana i indeks iskorišćavanja krava iznosio je 2445,21±17,49 dana, 1562,55±17,71 dana, 1094,17±12,28 dana i 58,68±0,32%. Uticaj odgajivačkog područja, godine rođenja i grupe laktacija na osobine dugovečnosti bio je vrlo značajan (P<0.01), dok je uticaj sezone rođenja krava bio značajan (P<0.05). Uzrast pri prvoj oplodnji visoko značajno (P<0.01) je uticao na uzrast pri izlučenju, dužinu produktivnog života i indeks iskorišćavanja krava, dok na ukupan broj muznih dana nije imao značajan uticaj (P>0.05). Dobijeni koeficijenti determinacije (R^2), na osnovu primenjenog modela, za sve osobine dugovečnosti bili su vrlo značajni (P<0.01) i kretali su se od 0,898 kod uzrasta pri izlučenju do 0,959 kod ukupnog broja muznih dana.

Ključne reči: dugovečnost, fiksni uticaji, kontinuelni uticaji, simentalske krave.

Acknowledgment

This work was supported by the Ministry of Education, Science and Technological Development, Republic of Serbia, project TR-31086.

References

ALLAIRE F.R., GIBSON J.P. (1992): Genetic value of herd life adjusted for milk production. Journal of Dairy Science 75, 1349-1356.

ANSARI-LARI M., MOHEBBI-FANI M., ROWSAH-GASRODASHTI A. (2012): Causes of culling in dairy cows and its relation to age at culling and interval from calving in Shiraz, Southern Iran. Veterinary Research Forum 3(4), 233-237.

BOGDANOVIĆ V., ĐEDOVIĆ R. (2003): Testiranje i metode procene priplodne vrednosti simentalskih bikova. Savremeni trendovi u mlekarstvu, Zlatibor, Zbornik radova, 46-50.

BOGDANOVIĆ V., ĐEDOVIĆ R., STANOJEVIĆ D., PETROVIĆ D.M., BESKOROVAJNI R., RUŽIĆ-MUSLIĆ D., PANTELIĆ V. (2012): Regional Differences in Expression of Milk Production Traits in Simmental Cows. Proceedings of the First International Symposium on Animal Science. November 8-10th, Belgrade, Serbia. Book I, 223-230.

CHIUMIA D. (2011): Vulnerability in holstein-friesian dairy cows: Risk factors for culling and effect of temperament on oestrus. M. Sc. thesis. The University of Edinburg.

DEKKERS J.C.M. (1993): Theoretical basis for genetic parameters of herd life and effects on response to selection. Journal of Dairy Science 76, 1433-1443.

DÜRR J.W. (1997): Genetic and phenotipic studies on culling in Quebec holstein cows. PhD Thesis, Department of Animal Science, MeGill University, Montreal, Canada.

FUERST C., SÖLKNER J. (1997): Improvemenst in a routine genetic evaluation for longevity in Catlle. Book of Abstracts of the 48th Annual Meeting of the European Association for Animal Production, Vienna, Austria, 25-28 August.

HARDER B., BENNEWITZ J., HINRICHS D., KALM E.(2006): Genetic parameters for health traits and their relationship to different persistency traits in German Holstein dairy cattle. Journal of Dairy Science 89, 3202-3212.

MAHER P., GOOD M., MORE S.J. (2008): Trends in cow numbers and culling rate in the Irish cattle population, 2003 to 2006. Irish veterinary Journal, 61(7), 455-463.

M'HAMDI N., ALOULOU R., BOUALLEGUE M., SATINDER K.B., BEN HAMOUDA M. (2010): Study of functional Longevity of Tunisian Holstein dairy cattle using a Weibull proportional hazard model. Livestock Science 132, 173-176.

MIGLIOR F., MUIR B.L., VAN DOORMAAL B.J. (2005): Selection Indices in Holstein Cattle of Various Countries. Journal of Dairy Science 88, 1255-1261.

NIENARTOWICZ-ZDROJEWSKA A., DYMARSKI Z., SOBEK Z., WOLE A.(2009): Culling reasons as related to lifetime dairy performance in Polish Friesian (Black-and-White) cows on Pawlowice farm in the years 1909-2006. Animal Science Papers and Reports 27(3), 173-180.

ORPIN P.G., ESSLEMONT R.J. (2010): Culling and wastage in dairi herds: An update on incidence and economic impact in dairy herds in the UK. Cattle Practice 18, 163-172.

PETROVIĆ D. M., BOGDANOVIĆ V., BOGOSAVLJEVIĆ-BOŠKOVIĆ S., ĐOKOVIĆ R. (2008): The effect of age at first insemination on reproductive, productive, longevity and lifetime production traits in simmental cows. Contemporary Agriculture 57(3-4), 150-157.

PETROVIĆ D. M., SKALICKI Z., GUTIĆ M., BOGDANOVIĆ V. (2004): The effect of paragenetic factors on longevity traits of Simmental cows. Biotehnology in Animal Husbandry 20(3-4), 23-29.

PINEDO P.J., DE VRIES A., WEBB D. W. (2010): Dynamics of culling risk with disposal codes reported by Dairy Herd Improvement dairy herds. Journal of Dairy Science 93, 2250-2261.

POGAČAR J., POTOČNIK K., KUMP I., DOLINAR A. (1998): Estimation ofstayability traits in black-and-white cows in Slovenia. 6th International Symposium ”Animal Science Days”, Portorož, Slovenia, Sept. 16-18, 1998.

RAGUŽ N. (2012): Genetsko vrednovanje dugovječnosti u populaciji simentalske i holstein pasmine goveda u Hrvatskoj. Doktorska disertacija. Poljoprivredni fakultet Osijek.

SEEGERS H., BEAUDEAU F., FOURICHON C., BAREÍLLE N. (1998): Reasons for culling in Frenc Holstein cows. Preventive Veterinary Medicine 36, 257-271.

SEWALEM A., MIGLIOR F., KISTEMAKER G.J., SULLIVAN P., VAN DOORMAAL B.J. (2008): Relationship between reproduction traits and functional longevity in Canadia dairy cattle. Journal of Dairy Science 91, 1660-1668.

SMITH J.W., ELY L.O., CHAPA A.M. (2000): Effect of region, herd size, and milk production on reasons cows leave the herd. Journal of Dairy Science 83, 2980-2987.

STOJIĆ P., BOJKOVIĆ-KOVAČEVIĆ S., BESKOROVAJNI R., JEREMIĆ I., PANTELIĆ V. (2012): Causes of cow culling in the tie stall system. Biotehnology in Animal Husbandry 28(4), 697-704.

STATSOFT INC. STATISTICA FOR WINDOWS, Version 6.0, Computer program manual. Tulsa: StatSoftJuc., 1995.

VAN RADEN P. M. (2004): Selection on net merit to improve life time profit. Journal of Dairy Science 87, 3125-3131.

ZAVADILOVÁ L., ŠTÍPKOVÁ M. (2013): Effect of age at first calving on longevity and fertiliti traits for Holstein cattle. Czech Journal of Animal Science 58(2), 47-57.

Received 21 August 2019; accepted for publication 24 September 2019