Estimation of genetic parameters and environmental effects on somatic cell count in Simmental and Holstein breeds

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Summary

The objective of this study was to estimate genetic parameters and environmental effects on somatic cell count in Croatian dairy cows. Data consisted of 861,417 test-day records for Simmental and 656,272 for Holstein cows. For Simmental breed, number of animals in pedigree was 123,199, while pedigree file for Holstein breed included 94,294 animals. A single-trait repeatability fixed regression test-day model was used to estimate genetic parameters. Fixed effects in the model were parity and calving season. Days in milk was fitted using Ali-Schaeffer lactation curve nested within parity. Age at first calving was modelled as quadratic regression. Direct additive genetic effect, herd, herd-test-date, and permanent environmental effect of cow within parity were included in the model as random effects. Variance components were estimated using Restricted Maximum Likelihood method as implemented in the VCE-6 program. Estimated heritabilities were 0.21 for Simmental and 0.15 for the Holstein breed. Permanent environmental effect explained 19 % of phenotypic variation in Simmental and 20 % in Holstein breed. Herd and herd-test-date accounted for another 9 % and 5 % of variability for Simmental breed. The effects of herd and herd-test-date explained 10 % and 5 % of phenotypic variance in Holstein breed.

Key words: somatic cell count, Simmental and Holstein breed,
environmental effects, genetic parameters

Introduction

Selection for higher milk production is stressful for dairy cows and disturbs cow body resistance, especially of mammary gland. Somatic cell count in milk (SCC) is used for managing udder health and is internationally accepted indicator of udder health (Muggli, 1993). Increased SCC reduces milk production (Harmon, 1994; Jones, 1998; Rudolphi, 2004) and changes occur in secretion, chemical composition, physical, bacteriological and technological traits of milk (Schutz et al., 1990; Harmon, 1994; Antunac et al., 1997). According to ICAR (2011), normal cow milk contains between 50,000 and 200,000 somatic cell/mL. Somatic cell count is influenced by genetic and environmental effects. The most important environmental effects are: stage of lactation (Schutz et al., 1990; Reents et al., 1995; Dodenhoff et al., 1999), age at calving (Harmon, 1994), calving season (Schutz et al., 1990), parity (Reents et al., 1995; Dodenhoff and Emmerling, 2008; Špehar et al., 2010a), status of infection (Dohoo and Meek, 1982; Harmon, 1994), milking and herd management (Jones, 1998; Dodenhoff et al., 1999; Mijić et al., 2005). Other effects, such as the number of milking per day, milking interval, feed intake, number of calves, conditions in the barn (humidity and temperature, exposure to stress or calming music) are less important or not recorded. Somatic cell count can be used as an indirect selection tool for mastitis reduction (Emanuelson, 1988). Many studies (Banos and

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Shook, 1990; Schutz, 1994; Reents et al., 1995; Liu et al., 2000) showed that SCC is low heritable trait. The advantages of test-day model (TDM) have led to increasing usage of test-day instead of lactation records and an implementation of test-day model for the cattle genetic evaluation. The TDM was firstly implemented for a routine genetic evaluation for milk production traits in Croatia (Špehar, 2010b). For SCC inclusion in the genetic evaluation, it is necessary to estimate the variance components. Therefore, the aim of this study was to develop fixed and random part of TDM for genetic evaluation and to estimate genetic parameters and environmental effects for SCC in Simmental and Holstein cattle in Croatia.

Material and methods

Test-day records from regular milk recording and pedigree information were included in data analyses for Simmental and Holstein breeds. Data were taken from the central database of Croatian Agricultural Agency for the period from December 2004 to August 2009. Daily milk yield and milk components were recorded according to the ICAR guidelines (ICAR, 2011). The AT4 method was used on family farms and BT4 on the enterprises. Data sets were prepared using SQL language for Simmental and Holstein breeds separately. A total of 861,417 test-day records for 65,111 Simmental cows were used in data analysis. For Holstein breed, data set contained 656,272 test-day records of 45,953 recorded cows. In order to obtain a normal distribution, logarithmic transformation for SCC was performed (Ali and Shook, 1980). Records from the first to the tenth parity were included in the analysis. Furthermore, parities from the seventh to the tenth were additionally joined into a common class (parity 7+) for Simmental breed due to the small number of records. For Holstein breed, records from the sixth to the tenth formed common parity class (parity 6+). Calving season was defined as year-season interaction. Four seasons within year were used and denoted from 1 to 4 as follows: spring (from March to May), summer (from June to August), autumn (from September to November), and winter (from December to February), respectively. Days in milk ranged within interval from five to 365 days for Simmental and to 400 days for Holstein cows. The age at calving was checked within parities to ensure reasonable ages according to parity. Pedigree file was prepared for each breed separately. All animals with records and their relatives (three generations) were included in the pedigree. A total of 123,199 animals were involved in the pedigree for Simmental breed. Pedigree file for Holstein breed contained 94,294 animals.

Test-day records were modelled using a single trait fixed regression repeatability test-day model. Fixed effects were analysed by a least square method using GLM (general linear models) procedure in the statistical package SAS (SAS, 2009). The model [1] that best fit logSCC was represented in the following scalar notation:

$$y_{ijklmno} = \mu + \sum_{q=0}^{4} b_{qi} t_{qijklmno} + S_k + b_5\left(x_{ijklmno} - \bar{x}\right) + b_6\left(x_{ijklmno} - \bar{x}\right)^2 + h_{jm} + htd_{jm} + a_n + p_{in} + e_{ijklmno} \qquad [1]$$

where
$y_{ijklmno}$ = individual test-day observation for somatic cell count,
$t_{ijklmno}$ = stage of lactation
b_{i0} = intercept for each parity (i = 1, 2, 3, 4, 5, 6, 7+) in Simmental, and (i = 1, 2, 3, 4, 5, 6+)
        in Holstein breed
b_{i1}, b_{i2}, b_{i3}, b_{14} = regression coefficients of the Ali-Schaeffer curve's nested within parity for each breed
S_k = calving season as class effect (k = 1, 2, 3 ..., 19) in Simmental and (k = 1, 2, 3, ..., 18)
        in Holstein breed
h_{jm} = random herd effect (l = 1, 2, 3, ..., 7,760) in Simmental and (l = 1, 2, 3, ..., 2,780)
        in Holstein breed
htd_{jm} = random herd-test-date effect (l = 1, 2, 3, ..., 861,417), in Simmental and (l = 1, 2, 3, ..., 656,272)
        in Holstein breed
a_n = direct additive genetic effect
p_{in} = random permanent environmental effect (mn = 1, 2, 3, ... 113,989) in Simmental and
        (mn = 1, 2, 3, ... 74,313) in Holstein breed
e_{ijklmn} = residual

Preliminary analysis showed that the Ali-Schaeffer's regression model (1987) had the best goodness of fit. The curve is given in the following form:

$$t_0 = 1, t_1 = t_{ijklmn}/305, t_2 = (t_{ijklmn}/305)^2,$$
$$t_3 = \ln(305/t_{ijklmn}), t_4 = (\ln(305/t_{ijklmn}))^2 \quad [2]$$

Test-day records and the pedigree data were coded prior to the covariance components estimation in the software package PEST (Groeneveld et al., 1990). Covariance components were estimated by the Restricted Maximum Likelihood (REML) method as implemented in the VCE-6 software package (Kovač et al., 2002).

Results and discussion

Simmental cows had lower average logarithmic SCC (logSCC) compared to Holstein cows (table 1). The minimum (-3.6) and the maximum logSCC (9.6) was equal due to the same restrictions for both breeds. However, average logSCC in milk of Simmental cows (3.07) was higher than values reported for Simmental cattle in Bavaria (Dodenhoff et al., 1999; Dodenhoff and Emmerling, 2008), in Italy (Vicario and Carnier, 2008) and Austria (Koeck et al., 2010).

Holstein cows had higher average logSCC (3.31) in milk compared to average logSCC reported by Reents et al. (1995), but lower than average logSCC for Italian Holstein cows (Vicario and Carnier, 2008). Generally, breeds specified for dairy production with faster milk flow are more sensitive to mastitis and consequently have higher average logSCC in milk.

The stage of lactation significantly affected (P<0.01) logSCC in both breeds. It was modelled using Ali-Schaeffer's lactation curve (Ali and Schaeffer, 1987) nested within parity due to differences in logSCC among parities for both breeds. The shape of logSCC curve is opposite compared to daily milk yield lactation curve due to negative correlation between them. The estimated lactation curves for logSCC by parity for Simmental breed are shown in figure 1a. LogSCC was the lowest in the first parity. At the beginning of lactation, logSCC was 3.5 and rapidly decreased approximately 30 days after calving to the lowest point of 2.2. LogSCC increased after the lowest peak and reached the value of 2.8 at the end of lactation. The shape of lactation curves for cows in later parities was steeper compared to the lactation curve of the first parity cows (Figure 1a). Cows in later parities had similar logSCC as cows in the first parity in early lactation. After the minimum point had been reached, a higher logSCC were observed towards the end of lactation compared to logSCC in the first parity. The highest logSCC was observed in the parity 7+ for Simmental breed. Similar pattern in logSCC increase was observed for Simmental cows in Germany (Dodenhoff and Emmerling, 2008) and Italy (Vicario and Carnier, 2008).

Lactation curves for logSCC in Holstein breed (Figure 1b), fitted by the Ali-Schaeffer's lactation curve (Ali and Schaeffer, 1987) within parity, showed differences compared to Simmental breed. At the beginning of lactation, the logSCC ranged from 4.0 in the first four parities to 4.5 for fifth and 6+ parity in Holstein cows (Figure 1b). The lowest logSCC differed among parities. It ranged from 2.6 for the first parity cows to 4.1 for cows in the third parity. LogSCC reached the lowest point around 40 days after calving followed by an increase towards the end of lactation. In the research of Schutz et al. (1990), similar logSCC for Holstein cows in Minnesota was observed for all parities (from 3.8 to 4.5 at the beginning to 3.2 and 4.7 at the end of lactation) to the values reported in this study. The lactation curve was flatter for the first parity cows compared to the lactation curve of cows in later parities. (Figure 1b). Similar to results obtained for Croatian Holstein cows, curves for first lactation Ontario

Table 1. Descriptive statistics for logSCC by breed

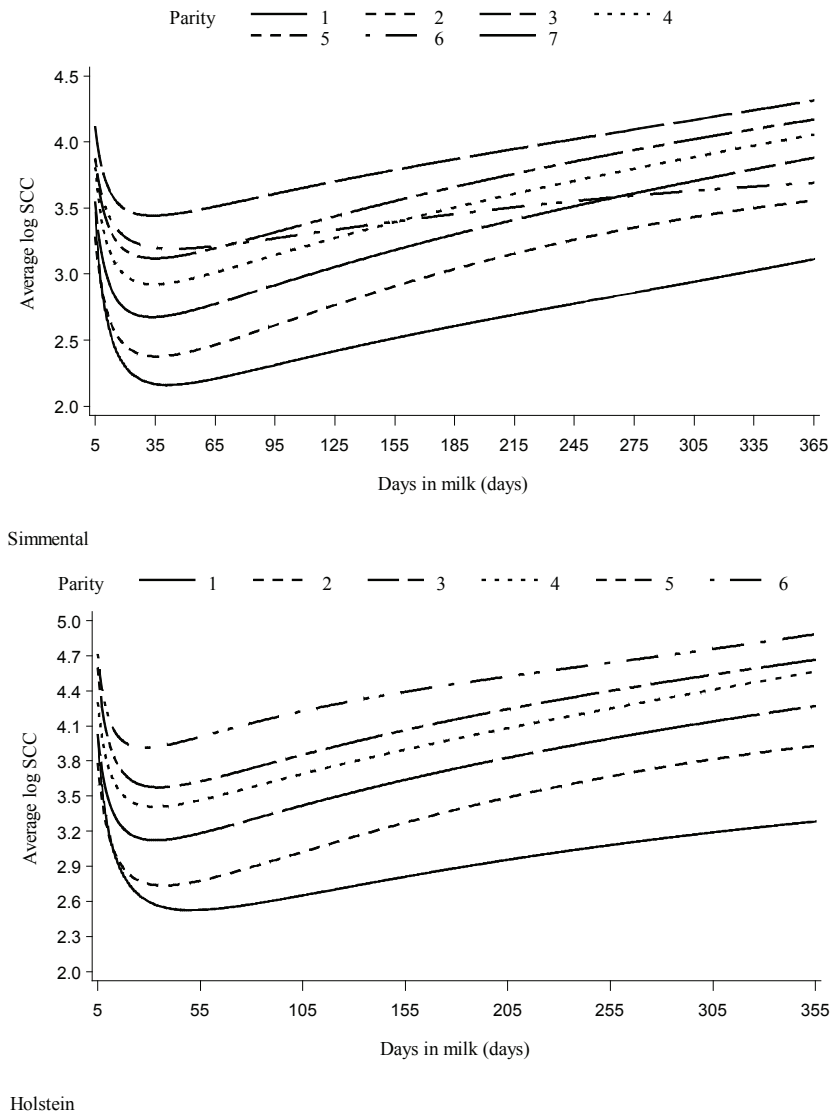| Breed	N	Mean	CV (%)	Min	Max
Simmental	861,417	3.07	68.95	-3.64	9.64
Holstein	656,272	3.31	63.80	-3.64	9.64

Simmental

Holstein

Figure 1a and 1b. Lactation curves of logSCC for cows in Simmental and Holstein breed

cows differed from curves in latter parities which become steeper after the minimum during the second month of lactation (Reents et al., 1994).

Age at the first calving modelled as quadratic regression had significant effect (P<0.01) on average logSCC (Figure 2). For Simmental breed, the highest proportion of first calving cows aged between 23 and 27 months. Cow at that age at first calving had average logSCC between 2.4 and 2.8. Relatively lower proportion of calving was at the age from 33 to 40 months and their average logSCC (from 2.8 to 3.2) was higher compared to early calving cows. An increase in logSCC by cow's age was reported by

Harmon (1994) and Dodenhoff et al. (1999).

Holstein cows had the highest proportion of calvings at the age from 24 to 28 months, with the average logSCC between 3.0 and 3.2. The average logSCC increased when cows became older at first calving. An increased trend of logSCC by age at the first calving was observed in the studies of Schutz et al. (1990), and Reents et al. (1995) for Holstein cows.

Calving season was modelled as year-season interaction. Differences in logSCC among calving seasons (Figure 3) were statistically significant (P<0.001). Calving season estimates for average
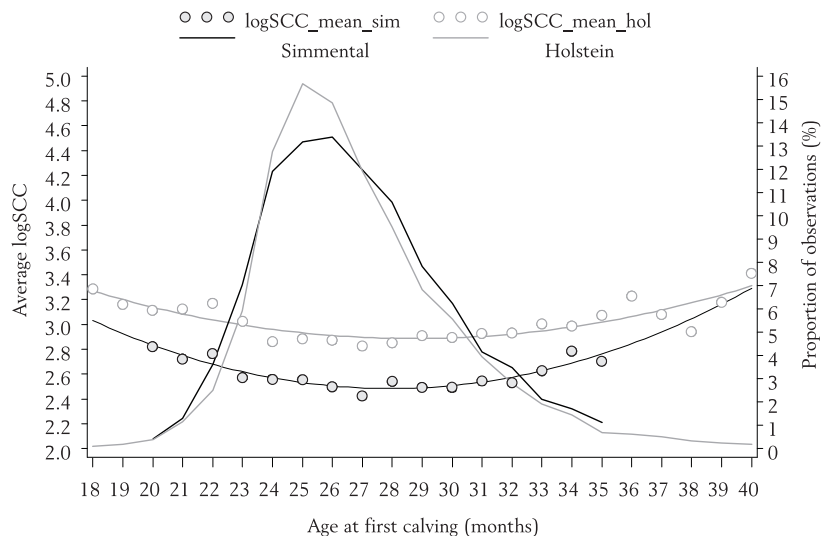
Figure 2. Average logSCC and proportion of records by age at first calving for Simmental and Holstein breed
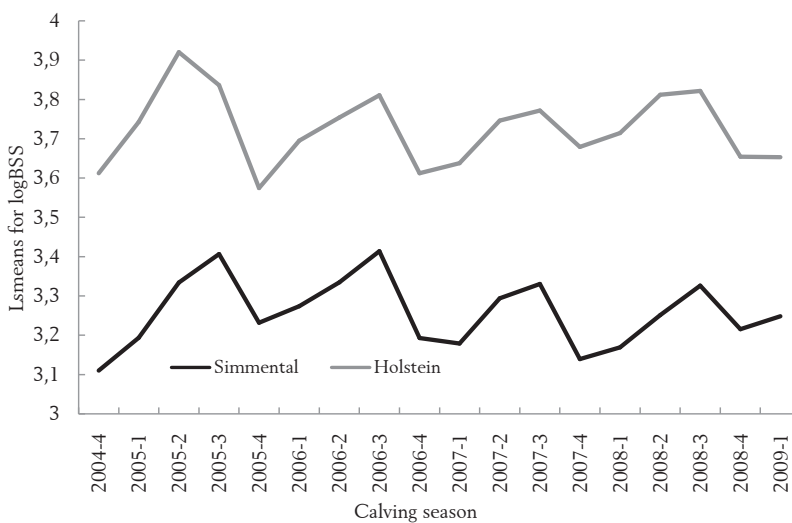

Figure 3. Average logSCC by calving season for Simmental and Holstein breed

logSCC showed similar trend in Simmental and Holstein breeds. Smaller differences in average logSCC were observed for Simmental cows compared to Holstein.

Simmental and Holstein cows that calved in summer and autumn had higher average logSCC compared to winter calving cows. The average logSCC ranged from 3.3 to 3.4 for Simmental and from 3.8 to 3.9 for Holstein cows that calved during summer and autumn. For winter calving Simmental cows, average logSCC was from 3.1 to 3.2, while

Holstein cows had average logSCC from 3.6 to 3.7. Holstein cows in the study of Schutz et al. (1994) and Harmon (1994) showed a similar pattern of logSCC dynamics.

Estimated heritability was 0.21 for logSCC in Simmental breed. Lower heritability was estimated for logSCC in Italian Simmental breed (0.085; Interbull, 2000) and in joint evaluation for Germany and Austria (0.10, 0.12, and 0.13 for the first, the second and the third parity; Interbull, 2000). For Simmental cows in Germany, estimates of heri-

Table 2. Estimated ratios for logSCC in Simmental and Holstein breed

Breed	h^2	p^2	c_h^2	c_{htd}^2	e^2
Simmental	0.21 ± 0.003	0.19 ± 0.002	0.09 ± 0.002	0.05 ± 0.001	0.46 ± 0.002
Holstein	0.15 ± 0.002	0.20 ± 0.002	0.10 ± 0.003	0.05 ± 0.001	0.50 ± 0.002

h^2 - heritability, p^2 - permanent environment, c_h^2 - herd, c_{htd}^2 - herd-test day, e^2 - residual

tability ranged from 0.05 to 0.13 using multiple-trait analysis (Dodenhoff and Emmerling, 2008). Higher heritability was obtained for logSCC in Czech Republic (0.274; Interbull, 2000) and Slovenia (0.29; Klemen Potočnik, 2010: Personal communication, Biotechnical Faculty, Zootechnical Department, e-mail: klemen.potocnik@bf.uni-lj.si).

Permanent environmental effect explained 19 % of phenotypic variance. Herd and herd-test-date accounted for another 9 % and 5 % of variability for Simmental breed. In Slovenian Simmental breed, estimated ratio for permanent environmental effect was 23 %, while herd effect covered 7 % of phenotypic variability (Klemen Potočnik, 2010: Personal communication, Biotechnical Faculty, Zootechnical Department, e-mail: klemen.potocnik@bf.uni-lj.si).

Estimated heritability was 0.15 in Holstein breed. Heritability in this study was similar to estimated heritability in France (0.15; Interbull, 2000). Slightly higher values were reported for countries participating to Interbull (2000) such as Germany (0.23), Switzerland (0.24), France and Estonia (0.23). Permanent environmental effect accounted for another 20% of total variance. In the research of Mostert et al. (2004), the permanent environmental estimates were 0.28 for the first, 0.31 for the second, and 0.34 for the third parity. The effects of herd and herd-test-date explained 10 % and 5 % of phenotypic variance in Holstein breed.

Conclusion

Results in this study showed that logSCC was affected with further environmental effects: stage of lactation, parity, age at the first calving and calving season in Croatian dairy breeds. Holstein cows had higher average logSCC compared to Simmental cows. LogSCC was the lowest in the first parity in

both breeds. The highest logSCC was observed in the 6+ parity class in Holstein as well as in the parity class 7+ for Simmental cows. SCC has increased at the beginning of lactation, decreasing thereafter and reached a minimum between the 5th and 9th weeks of lactation. After lowest point is reached, SCC increases towards the end of lactation when it had maximum value. The average logSCC increased when cows became older at first calving. The lowest SCC had cows that firstly calved at the age between 27 and 29 months in both breeds. Cows calved in winter season (December to February) had the lowest SCC in both breeds. The estimated heritability of logSCC in Simmental breed was 0.21 and 0.15 in Holstein. The values are consistent with previous studies which used a similar model. Permanent environmental effect explained 19 % of total variance in Simmental and 20 % in Holstein breed. The effects of herd effect explained 9 % in Simmental and 10 % of phenotypic variance in Holstein breed, while herd-test-date accounted for another 5 %. The results presented in this study show that TDM with fixed regression can be used for genetic evaluation of SCC in Simmental and Holstein cattle breeds in Croatia. Organized breeding program can result in lower SCC and strengthen resistance to mastitis, but it cannot replace good SCC management.

Utjecaj genetskih i okolišnih parametara na broj somatskih stanica u mlijeku simentalske i holstein pasmine goveda

Sažetak

Cilj ovog rada bio je ispitati i ocijeniti utjecaj okolišnih čimbenika na varijabilnost broja somatskih stanica u mlijeku i procijeniti komponente varijance. Ukupno je analizirano 861.417 dnevnih zapisa krava

simentalske i 656.272 dnevna zapisa krava holstein pasmine. Porijeklo simentalske pasmine uključuje 123.999, a porijeklo holstein pasmine 94.294 životinje. Za procjenu genetskih parametara korišten je model dnevnih zapisa s fiksnom regresijom. Fiksni dio modela je uključivao utjecaj rednog broja laktacije i sezone teljenja. Stadij laktacije je opisan Ali-Schaefferovom funkcijom ugniježđenom unutar rednog broja laktacije, dok je dob kod prvog teljenja opisana kvadratnom regresijom. Slučajni dio modela je određen stadom, interakcijom stado-dan testiranja, direktnim aditivnim genetskim i stalnim okolišnim utjecajem. Procijenjeni heritabilitet za broj somatskih stanica u mlijeku krava iznosio je $h^2 = 0,21$ za simentalsku pasminu, a za holstein pasminu $h^2 = 0,15$. Stalnim utjecajem okoliša je pojašnjeno 19 % varijabilnosti za simentalsku, te 20 % za holstein pasminu. Utjecajem stada i interakcije stado-dan kontrole za simentalsku pasminu je pojašnjeno 9 % odnosno 5 % od ukupne varijabilnosti broja somatskih stanica. Za holstein pasminu je utjecaj stada i interakcije stado-dan kontrole pojasnio 10 % odnosno 5 % varijabilnosti.

Ključne riječi: broj somatskih stanica, kravlje mlijeko, pasmina, okolišni i genetski parametri

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