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# SOMATIC CELL LEVEL IN DAIRY COWS' MILK DURING EXTENDED LACTATION*

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**Abstract**

**Milk analysis was performed in Black-and-White cows with a different percentage of Holstein-Friesian (HF) genes, which calved in 1995–2008 and were included in the milk recording programme. The aim of the present study was to determine the somatic cell level in milk obtained during the extended lactation phase (from day 306 to the end of lactation) compared to the standard lactation. The average somatic cell count in the milk of cows in extended lactation was 409,000 in the standard lactation of 305 days, 542,000 in the extended lactation phase and 427,000 per mL in full lactation of 381 days. Somatic cell count in the milk produced during the extended lactation phase (from day 306 to the end of lactation) was significantly higher compared with the milk harvested during the 305-day lactation. The lowest average somatic cell score (SCS) per mL raw milk in the extension phase was determined in the milk of primiparous cows (3.83). The factors which significantly affected the somatic cell count in the milk of cows extending their standard lactation included parity (lactation) and average daily milk yields from day 306 until the end of lactation. The correlation coefficients calculated for the somatic cell score (SCS) in standard lactation and in extended lactation phase, within selected factors, indicate that there was a positive correlation for both the lactation groups (standard lactation and extension period) as well as lactation (parity) ($r_p$ = 0.23 and $r_p$ = 0.33; P<0.01). It was also demonstrated that somatic cell count was on the decrease with increasing daily milk performance during extended lactation ($r_p$ = –0.23; P<0.01).**

**Key words: dairy cows, lactation, extension, somatic cell count**

Milk production intensification has led in many countries, including Poland, to increased milk yields per cow. Higher milk yield resulted in changes in cow productivity, including extended lactations, and reduced fertility (Sölkner et al., 2000; Seeland and Henze, 2003; Bielfeldt et al., 2004; Windig et al., 2006; Sawa and Bogucki, 2009 a). However, according to Knight (2005), the modern dairy cow should be characterized not only by high levels of milk yield but also longer lactations. Lactation is sustained by regular suckling or milking. Without these stimuli, milk secretion

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is stopped, the current secretory cells undergo apoptosis and new ones are not formed (Wilde et al., 1999). Regulation (EC) No. 853/2004 of The European Parliament and of The Council of 29 April 2004 on the specific hygiene rules for food of animal origin, states that raw cow's milk should not contain more than 400,000 cells/mL.

The increase in milk yield results in a number of problems including lactation extension beyond the conventional 10-month period. The results of the authors' studies carried out in cows which calved in 2000–2003 revealed as many as 55% spontaneously extended lactations, by 82 days on average (Salamończyk and Guliński, 2007). The changes were associated with an import of purebred Holstein-Friesian animals from Holland and Germany, crossing with this breed and improved balancing of feed rations for dairy cows. Bertilsson et al. (1998), Knight et al. (1998) and De Vries (2006) suggest that cows with extended lactations may generate larger profits as a result of increased lifetime milk yield, extended length of productive life, and lower cost of herd replacement.

Both health and welfare of cows benefit enormously from extended calving intervals (De Vries, 2006). However, there is a paucity of information on the quality of milk harvested during the last months of lactations exceeding 10 months.

The aim of the present study was to analyse the somatic cell level in milk obtained during the extended lactation phase, that is from day 306 to the end of lactation compared to the standard lactation.

## Material and methods

Examinations were conducted of cows calving in 1995–2008, raised on private farms and included in the milk recording programme. Analyses were performed of 23,733 full lactations which were at least one day longer than the standard 305-day lactation but not longer than 600 days. A total of 223,792 milk samples were examined (standard lactation: 177,158 samples). The data for analysis were results of milk recording in 350 dairy herds.

Data concerning daily milk performance were obtained from animal records kept by the Polish Federation of Cattle Breeders and Dairy Farmers. Physical and chemical milk evaluation was performed by laboratories accredited by the Polish Accreditation Centre which apply the quality system in accordance with the Standard PN-EN ISO/IEC 17025 and operate under ICAR guidelines.

The following definitions of the evaluated lactations, which constitute the main factor influencing SCC and SCS, are employed throughout the present work: standard lactation – a 305-day lactation; lactation extension phase – the period from day 306 to the end of lactation when a cow is dried off.

The present work evaluated the effect on somatic cell counts (SCC; th/mL) and somatic cell score (SCS) in the milk of cows in the extended lactation phase of the following factors: full lactation length (306–335, 336–365, 366–395, 396–425, 426–455, 456–485, 486–515, 516–545, 545–600 days); cow's parity (parity: 1; 2 and 3; 4 and higher); calving season (September-November; December-February;

March-May; June-August); and average daily milk yield (in kg) in the extended lactation – beyond 305 days (≤5; 5.1–7.5; 7.6–10; 10.1–12.5; ≥12.6 kg).

Somatic cell count (SCC) was log-transformed to somatic cell score (SCS) as follows (Wiggans and Shook, 1987): SCS = log2(SCC/100,000)+3.

In order to precisely characterize the assessed population of Black-and-White cows with a different percentage of Holstein-Friesian (HF) genes, the actual yields of milk characterized by a given fat content and protein content were expressed as energy-corrected milk (ECM) which contains 3.50% fat and 3.20% protein according to the formula (Bernard, 1997):

$$ECM\ (kg) = (0.3246 \cdot kg\ milk) + (12.86 \cdot kg\ fat) + (7.04 \cdot kg\ protein)$$

Statistical analysis included two-way variance analysis by the method of least squares according to the following linear model:

$$Y_{ijk} = \mu + a_i + b_j + (ab)_{ij} + e_{ijk}$$

where:

$Y_{ijk}$ – dependent variable (SCS);

$\mu$ – overall mean;

$a_i$ – effect of lactation definition ($i$ = standard lactation, extended lactation phase);

$b_j$ – effect of $j$-th lactation length ($j$ = 306–335; 336–365; 366–395; 396–425; 426–455; 456–485; 486–515; 516–545; 546–600); or $j$-th parity ($j$ = 1, 2 and 3, 4 and higher), or $j$-th average daily milk yield in the extended lactation phase (beyond 305 days) ($j$ = ≤5; 5.1–7.5; 7.6–10; 10.1–12.5; ≥12.6); or $j$-th calving season ($j$ = September-November; December-February; March-May; June-August);

$(ab)_{ij}$ – interaction of lactation definition with lactation length or parity or calving season or average daily milk yield in the extended lactation phase (beyond 305 days);

$e_{ijk}$ – residual error.

Analysis included one-way and two-way ANOVA with interaction, using Tukey's honestly significantly different procedure.

The Wood's mathematical model was used to fit lactation curves of SCC (Wood, 1976). The model can be expressed by function:

$$Y_n = an^b e^{cn}$$

where:

$Y_n$ – is the SCC in the $n^{th}$ month,

*a, b* and *c* – define the curve of somatic cells count of *a* character *y* at month of lactation *n*.

Coefficients of phenotypic correlations were estimated to determine relationships between SCS in standard lactation or SCS in extended lactation phase and the factors chosen for assessment (full lactation length, parity and average daily milk yields over the 305-day period). The Pearson's correlation coefficient was calculated at $P<0.01$.

Statistical calculations used the ANOVA, GLM and CORR procedures of the SAS package (ver. 9.3).

## Results

Table 1 presents details of milk performance, somatic cell counts (SCC) and somatic cell score (SCS) in the milk of the cow population under study during the standard lactation (305 days), extended lactation phase and full lactation. The average ECM for the population of cows which calved in 1995–2008 was 6847 kg for 305-day lactation and 8051 kg for full lactation lasting 381 days, on average. Thus, extended lactation was 76 days longer than standard lactation and during this period cows produced 17.6% of the milk amount harvested during standard lactation (ECM in standard lactation = 100%).

Table 1. Descriptive statistic for the population of cows which extended their standard lactation

| Type of lactation | Variable | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|---|
| Standard lactation | ECM yield (kg) | 6847 | 1723 | 1924 | 17946 |
| | SCC (×1000/mL) | 409 | 584 | 11 | 9992 |
| | SCS | 4.13 | 1.57 | 0.01 | 9.64 |
| Extended lactation phase | Length (days) | 76 | 65 | 1 | 295 |
| | ECM yield (kg) | 1204 | 1167 | 3 | 9289 |
| | SCC (×1000/mL) | 542 | 1004 | 20 | 12060 |
| | SCS | 4.50 | 1.55 | 0.68 | 9.91 |
| Complete lactation | ECM yield (kg) | 8051 | 2347 | 2510 | 25553 |
| | SCC (×1000/mL) | 427 | 574 | 3 | 12060 |
| | SCS | 4.29 | 1.50 | 0.06 | 9.91 |

The purpose of the work was to evaluate the quality of milk obtained during the extended lactation phase, that is from day 306 to the end of lactation compared to the standard lactation. Data contained in Table 2 on SCS in standard lactation and lactation extension phase according to the experimental factors indicate that there were significant ($P<0.01$) differences in milk quality between lactation groups and individual levels of factors. These differences are the average differences between SCS for the extension period and SCS for the standard lactation, calculated using one-way analysis of variance (ANOVA) for all data. For each treatment the SCSs were lower in standard lactation than the lactation extension phase. The greatest differences between SCS in lactation extension phase and standard lactation for individual factors were found for cows with the full lactation of 546 to 600 days (0.50), in cows in parity 2 or 3 and 4 or higher (0.46, 0.50), cows which calved in September-November and June-August (0.52, 0.46) and cows whose average daily milk yield from day 306 to the end of lactation was less than 10.0 kg (1.43, 0.79, 0.48).

Table 2. Somatic Cell Score (SCS) in 305-day and extended lactation phase, and average differences between SCS in extended and standard lactation

| Factors | Average daily milk yield in full lactation (kg) | SCS in standard lactation (A) | SCS in extended lactation phase (B) | (B – A) |
|---|---|---|---|---|
| Full lactation length (days) | | | | |
| 306–335 | 19.43 a | 4.10 * | 4.47 b * | 0.44 ab |
| 336–365 | 19.39 ab | 4.13 * | 4.47 b * | 0.36 bc |
| 366–395 | 19.29 ab | 4.17 * | 4.47 b * | 0.30 c |
| 396–425 | 19.03 bc | 4.12 * | 4.52 ab * | 0.39 abc |
| 426–455 | 18.75 c | 4.23 * | 4.57 ab * | 0.34 bc |
| 456–485 | 18.72 c | 4.18 * | 4.55 ab * | 0.36 bc |
| 486–515 | 18.15 d | 4.14 * | 4.51 ab * | 0.36 bc |
| 516–545 | 17.98 d | 4.11 * | 4.50 ab * | 0.40 abc |
| 546–600 | 17.90 d | 4.14 * | 6.63 a * | 0.50 a |
| Parity | | | | |
| 1 | 17.67 c | 3.69 c * | 3.83 c * | 0.12 b |
| 2 and 3 | 20.01 a | 4.10 b * | 4.57 b * | 0.46 a |
| 4 and higher | 19.48 b | 4.60 a * | 5.12 a * | 0.50 a |
| Calving season (months) | | | | |
| Sep-Nov | 19.72 a | 4.02 b * | 4.54 b * | 0.52 a |
| Dec-Feb | 19.75 a | 4.15 a * | 4.39 d * | 0.25 b |
| Mar-May | 18.55 b | 4.21 a * | 4.47 c * | 0.25 b |
| Jun-Aug | 18.54 b | 4.16 a * | 4.62 a * | 0.46 a |
| Average daily milk yields over the 305-day period (kg) | | | | |
| ≤5.0 | 15.16 d | 4.48 a * | 5.91 a * | 1.43 a |
| 5.1–7.5 | 15.30 d | 4.39 a * | 5.18 b * | 0.79 b |
| 7.6–10.0 | 16.33 c | 4.26 b * | 4.73 c * | 0.48 c |
| 10.1–12.5 | 17.78 b | 4.11 c * | 4.48 d * | 0.36 d |
| ≥12.6 | 21.60 a | 4.04 c * | 4.23 e * | 0.18 e |
| Average | 19.10 | 4.13 * | 4.50 * | 0.37 |

a, b, c – means in columns, followed by different letters differ significantly at P<0.05.

* – means in rows, between SCS for standard lactation and SCS for extension of standard lactation differ significantly at P<0.01.

The next step of the study was to examine, in terms of SCS, the relationships between lactation kind (standard or extended lactation phase) and the following factors: full lactation length, parity and average daily milk yields from the 305-day period (Table 3). Apart from the relation between the length of full and standard lactation, the calculated correlation coefficients were statistically significant (P<0.01). Comparison of correlation coefficients between types of lactation (standard and extended lactation) calculated for SCS within individual factors revealed that two factors exerted the greatest influence on milk quality, that is parity and average daily milk yields over the 305-day period. The evaluation of the effect of parity on SCS in standard lactation ($r_p$ = 0.23) and SCS in extended lactation phase ($r_p$ = 0.33) indicated that as the number of lactations advanced the level of somatic cells increased. SCS increased more in lactation extension phase, that is beyond 305 days.

The average daily milk yield over the 305-day period was the second factor which significantly influenced SCS mainly in the lactation extension phase. The correlation coefficient describing this relationship was $r_p$ = –0.23, which means that there was a highly significant (P<0.01) association of milk yield beyond 305 days and somatic cell count over this period. Increased average daily milk production in the lactation extension phase reduced SCC in milk in this period. This is probably because milk producers take more care of the health of high-performing cows or because milk components (also somatic cells) are thinned in a greater amount of milk (Table 3).

Table 3. Correlation ($r_p$) coefficients for SCS in standard lactation or SCS in extended lactation period (x) and factors examined (y)

| Factors | SCS in standard lactation | SCS in extended lactation period |
|---|---|---|
| Full lactation length (days) | 0.003 | 0.03 ** |
| Parity | 0.23 ** | 0.33 ** |
| Average daily milk yields over the 305-day period (kg) | –0.08 ** | –0.23 ** |

** – P<0.01.

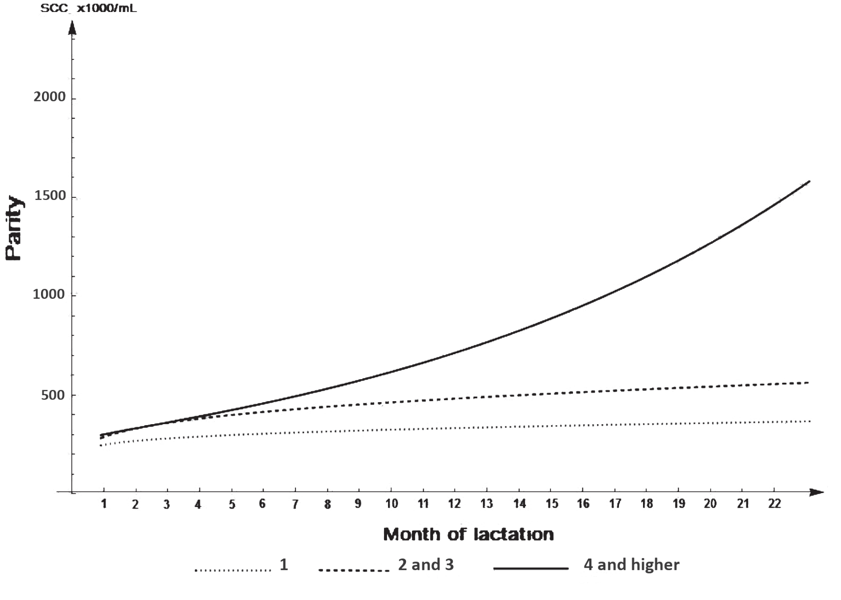


Figure 1. Somatic cell counts (x1000 cells/mL) in the milk of cows in extended full lactation according to parity

In order to better present the effect of parity on SCC in milk over the full extended lactation, curves were drawn according to Wood's model (Figure 1). The curve for SCC (th/mL) for first-parity cows is flat and SCC is at the same low level during the full lactation. The SCC curve (th/mL) for second- and third-parity cows is flat, too, although the milk of these cows contained more somatic cells over the whole period of extended full lactation, compared with first-parity cows. The same curve for the cows in parity 4 or higher is constantly on the increase from the beginning of lactation. The present work does not present SCC curves for the groups of cows divided according to the factor "average daily milk yields over the 305-day period" because the fit of empirical data in the Wood's model was too small.

## Discussion

One of the effects of very high milk performance is prolonged time when the cow produces milk after calving, a shorter dry period or even no dry period (Krzyżewski and Reklewski, 2003). A factor that influences the lactation length is also the somatic cell count in milk. SCC is often used as an index of udder health, and in the EU a maximum limit for saleable milk is set at 400,000 cells/mL. Studies by Sawa and Piwczyński (2003) have demonstrated longer lactations of cows which had suffered from mastitis at least once. The difference between the length of lactation in cows whose milk contained, over the whole lactation, not more than 100,000 SCC per mL, and cows with the milk SCC of over 1 000,000 was almost 30 days. Österman (2003) and Sorensen et al. (2008) have indicated that extension of lactation does not threaten milk quality. The gradual increase that was observed in SCC across the course of lactation is related to declining epithelial integrity, not to disease (Sorensen et al., 2008). According to Bertilsson et al. (1997), at the final stage of extended lactation milk is poor raw material for processing. Although decreasing milk yields are accompanied by increased protein contents, caseins are progressively degraded by proteolytic enzymes. Such a process at the end of lactation indicates limited survival of secretory epithelium. At the final stage of lactation sodium content increases and production of smaller fat balls are accompanied by increased fat content of milk. Our study also revealed that in the last months extended lactation milk was characterized by much lower quality, that is higher somatic cell content, than the milk collected in the first 10 months after calving.

Similar conclusions were made by other authors. For instance, studies by Österman et al. (2005) in primiparous cows revealed no significant differences in milk quality during the 18-month calving interval. However, many authors (Blackburn, 1966; Harmon, 1994; Österman et al., 2005) have reported a marked increase in ln SCC in multiparous cows over the last weeks of lactation, which they ascribed to a small amount of milk produced at the end of lactation. Österman et al. (2005) also claim that extension of the calving interval to 18 months results in no unfavorable influence on milk quality, irrespective of milking frequency.

It was demonstrated in this paper that the highest quality, in terms of somatic cell count, throughout the lactation period and also in the extended lactation phase was determined in the milk of first parity cows. Similar are the findings of Galton (1997) and Arbel et al. (2001), who reported that extended lactations are more beneficial for primiparous cows because their lactations are more persistent, and their fat and protein yields increase during the course of lactation.

It is widely known and confirmed in this research (Stenzel et al,. 2001; Gnyp et al., 2006; Haile-Mariam and Goddard, 2008; Cole et al., 2009) that a somatic cell count increases with cow's age. Haile-Mariam and Goddard (2008) have found that when lactation progresses beyond 305 days up to 540 days, log SCC, particularly in the second parity HF cows, increases.

Many authors who attempted to evaluate the effect of lactation (successive month) on somatic cell counts have indicated that SCC increases with progression of lactation. Stenzel et al. (2001) demonstrated that as lactation progressed there was observed a significant increase in somatic cell count from 438.9 th/mL at the beginning of lactation to 526.5 th/mL in the extended lactation phase. Sawa and Bogucki (2009 a) revealed that as lactation progressed, there was observed a 10–12% increase in the share of milk samples which contained more than 400,000 somatic cells per mL and could not be collected.

In conclusion, somatic cell count in the milk during the lactation extension phase (beyond 305 days) was on average higher by 133,000 per mL compared with standard lactation. The extension of lactation is not associated with poorer milk quality in youngest cows only (primiparous cows) and cows producing an average of at least 12.6 kg milk daily during this period. The correlation coefficients demonstrated that milk quality significantly (P<0.01) deteriorated in successive months of lactation, with successive parities, and reduced milk performance over the lactation extension phase.

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**Poziom komórek somatycznych w mleku krów w laktacji przedłużonej**

STRESZCZENIE

Analizie poddano mleko krów czarno-białych, z różnym udziałem genów rasy hosztyńsko-fryzyjskiej, będących pod oceną wartości użytkowej, wycielonych w latach 1995–2008. Celem badań była ocena zawartości komórek somatycznych w mleku pozyskanym w okresie przedłużenia laktacji (od 306. dnia do końca laktacji) w porównaniu do laktacji standardowej. Średnia LKS w mleku krów przedłużających laktację wynosiła: 409 tys. w laktacji standardowej (305-dniowej), 542 tys. w okresie przedłużenia laktacji oraz 427 tys. w 1 ml w laktacji pełnej trwającej średnio 381 dni. Zawartość komórek somatycznych w mleku z okresu przedłużenia laktacji standardowej (od 306. dnia do końca laktacji) była istotnie wyższa w porównaniu do mleka pozyskanego w ciągu laktacji 305-dniowej. Najniższą średnią liczbę komórek somatycznych (SCS), w 1 ml mleka surowego z okresu przedłużenia, stwierdzono w mleku pierwiastek (3,83). Do czynników, które znacząco wpływały na LKS w mleku krów w okresie przedłużenia laktacji, należały liczba dotychczasowych wycieleń oraz średnia dobowa wydajność mleka z okresu od 306. dnia do końca laktacji. Współczynniki korelacji obliczone dla punktacji komórek somatycznych (SCS) w laktacji standardowej oraz w okresie przedłużenia laktacji, w obrębie wybranych czynników, wskazały na istnienie dodatniej korelacji dla obu grup laktacji (standardowa i okres przedłużenia) oraz kolejnej laktacji (wycielenia) ($r_p$ = 0,23 i $r_p$ = 0,33; P<0,01). Wykazano również, że zawartość komórek somatycznych zmniejszała się wraz ze wzrostem dobowej wydajności mleka w okresie przedłużenia laktacji ($r_p$ = –0,23; P<0,01).