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# The relationships between the somatic cell counts in the milk and the fertility of Polish Holstein-Friesian cows

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**Abstract**: The aim of the study was to analyse the relationship between the somatic cell counts in the milk (the udder health status indicator) and the cow's fertility, taking the influence of the selected factors into account. The udder health status was determined based on the somatic cell count of the milk from 88 745 test-day records from 55 685 Polish Holstein-Friesian cows. The test-day measurements were made up to 30 days before the first insemination, during the period up to 180 days of the first and second lactation. Because the somatic cell count showed high variation and is not normally distributed, the data were transformed to the natural logarithm scale. Based on the results of the statistical analysis, it was shown that with the increase in the number of somatic cells in the milk, the calving intervals were extended by 11 days ($P \leq 0.01$), the service period by around 4 days ($P \leq 0.05$), the increase in the services per conception by 0.11 ($P \leq 0.01$). There was a statistically significant correlation, weak on the Guilford scale, between the natural logarithm of the somatic cell count and the fertility of the cows: the calving interval – CI ($r = 0.050^{**}$, $P \leq 0.01$), service period – SP ($r = 0.016^{**}$) end services per conception – SPC ($r = 0.019^{**}$). Monitoring the number of somatic cells in the milk could contribute to improving the fertility of the cows in particular: in the second lactation in the double lactation (for the CI ($r = 0.059^{**}$)); in herds with a production level of 7000–9000 kg of milk (for the CI ($r = 0.055^{**}$), the SP ($r = 0.022^{**}$) and the SPC ($r = 0.024^{**}$)); the daily productivity of > 40 kg (for the CI ($r = 0.052^{**}$), the SP ($r = 0.033^{**}$) and the SPC ($r = 0.029^{**}$)), the number of cows in the herd of > 200 (for the CI ($r = 0.061^{**}$), the SP ($r = 0.034^{**}$) and the SPC ($r = 0.033^{**}$)), in the autumn season of the first insemination (for the CI ($r = 0.072^{**}$), the SP ($r = 0.027^{**}$) and the SPC ($r = 0.031^{**}$)). The magnitude of these correlations varied within the classes of the factors such as the daily production level, the age of cows´ lactation number, the season of the first insemination, the herd production level, and the herd size. It appears that the somatic cell count results obtained from the periodic milk recording, considered as an indirect measure of the udder health and used when deciding on the mastitis treatment, could be a useful tool for controlling the fertility in the cows.

**Keywords**: cow fertility; mastitis; correlations; calving interval; service period; services per conception

The somatic cell count (SCC) is a commonly used method for evaluating the milk quality and udder health status. The main factor that causes SCC to exceed the physiological levels is mastitis (Skrzypek et al. 2007). The average genetic correlation coefficient between the udder inflammation

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and SCC is 0.6 and ranges from 0.1 to 0.8 according to different authors (Kadarmideen et al. 2000; Morek-Kopec et al. 2009; Olechnowicz and Jaskowski 2013).

Milk from a healthy udder contains no more than 100 000 cells per 1 ml, 100 000 to 200 000 cells in multiparous cows is indicative of minor and non-specific disturbances in the udder functioning, while levels above 200 000 cells are a sign of infection with pathogenic microorganisms and the presence of inflammation (Juozaitiene and Juozaitis 2005; Skrzypek et al. 2007; Olechnowicz and Jaskowski 2013).

The results concerning the effect of udder inflammation on the reproductive parameters show that mastitis diagnosed during the period preceding insemination has a negative effect on fertility of Holstein-Friesian cows (Morek-Kopec et al. 2009; Hudson et al. 2012). Other studies (Rahman et al. 2012; Olechnowicz and Jaskowski 2013; Isobe et al. 2014) also reported that mastitis occurring after insemination has a negative effect on the fertility. Mastitis contributes to an almost three-fold increase in pregnancy loss during the 45 days after the successful insemination (Hertl et al. 2010). According to Pinedo et al. (2009) and Hertl et al. (2010), udder inflammation contributes to the incidence of oestrous cycle disturbances. Morris et al. (2013) indicate that elevated milk SCC is paralleled by a delay in the onset of oestrus signs, which are markedly weaker. In cows with mastitis, the postpartum luteal activity even begins 7 days later than in healthy cows (Dobson et al. 2007). Kadarmideen et al. (2000) demonstrated genetic correlations between mastitis and fertility (the CI, SPC, reproductive rest period, RRP) ($r$ = 0.21–0.40). Isobe et al. (2014) showed high negative correlations (–0.74 to –0.75, $P < 0.05$) between the milk somatic cell count and the day of the first ovulation postpartum. Also, an analysis of the collated data by Berry et al. (2014) showed unfavourable correlations between the milk SCC and the fertility in cows. Heringstand and Larsgard (2010) reported a genetic correlation between clinical mastitis and fertility traits ($r$ = 0–0.41), which was confirmed, among others, for Norwegian Red cows; this suggests that the selection of the cows for the increased resistance to the clinical forms of mastitis may contribute to improving fertility. A 20–80% reduction in the conception rate due to clinical mastitis (or increased SCC), observed during the insemination period, was also found in cows by Hudson et al. (2015), although they showed, using a probabilistic sensitivity analysis, that for the majority of the possible scenarios, the associations between the udder inflammation measured by clinical mastitis or SCC and the reproductive performance of a dairy herd may be weak, despite earlier studies to the contrary. It is, therefore, appropriate to further explore this subject so as to address doubts about the relationship between the udder health status and the reproductive efficiency.

The aim of the study was to analyse the relationship between the somatic cell counts in the milk (the udder health status indicator) and the cow's fertility, taking the influence of the selected factors into account.

## MATERIAL AND METHODS

The data for the study were obtained from the SYMLEK database. The data refer to cows calved for the first time in the period of 2005–2012 and used until the end of 2014. The analysis included 88 745 rest-day records for 55 685 Polish Holstein-Friesian primiparous cows (the Black-and-White variety) under the milk recording scheme in the Pomerania and Kujawy regions; the second lactation cows amounted to 33 060, in 1835 herds. For each cow, i.e., the lactation of the cow, the following data were collected: the calving interval (CI) – the number of days between the consecutive calvings; the service period (SP) – the number of days between the first and successful insemination; the services per conception (SPC) – the number of services required to conceive; the somatic cell count of the milk from the test-day records obtained up to 30 days before the first insemination, during the period up to 180 days of the first and second lactation. Because the SCC shows high variation and is not normally distributed, the data were transformed in the program EXCEL to a natural logarithm scale (LNSCC).

The effect of the udder health status on the cow's fertility (CI, SP and SPC) was analysed based on the following classes of SCC per ml of milk: ≤ 1 000 000, 100 001–200 000, 200 001–400 000, 400 001–1 000 000, and > 1 000 000 GLM (SAS 2014). The CORR procedure (SAS 2014) was used to calculate the coefficients of the simple correlation between the log-transformed values of the

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milk somatic cell count (LNSCC) and the indicators of the cow's fertility, taking the effects of the cow's lactation number (the first and the second lactation, i.e., parity), the herd production level (≤ 7000, 7001–9000, > 9000 kg of milk), the season of the first insemination (spring: March–May; summer: June–August; autumn: September–November; winter: December–February), the lactation period during the first insemination (≤ 60, 61–90, 91–120, 121–150, 151–180 days), and the number of cows in the herd (≤ 20, 21–50, 51–200, > 200 cows) into account.

## RESULTS

The analysis of the fertility parameters shows that the cows were characterised by intermediate fertility (CI – 450 days, SP – 54.8 days, SPC – 2.20) (Table 1). The somatic cell count of the milk, often regarded as an indicator of the udder health status (Skrzypek et al. 2007), is a factor significantly associated with the investigated fertility parameters, the SPC in particular. The higher the SCC in the milk, which reflects the presence and the severity of the mastitis, was associated at the CI and SP with a slightly, gradually higher and higher values (by about 11 and 4 days) ($P \leq 0.05$ and $P \leq 0.05$), respectively. A similar tendency for a deterioration in the fertility with advancing mastitis was noted for the SPC (about 0.11) ($P \leq 0.01$).

There was a statistically significant correlation, weak on the Guilford scale, between the LNSCC and the fertility of the cows (Table 2). Higher LNSCC values were associated with a longer CI ($r$ = 0.050**) and SP ($r$ = 0.016**) as well as an increase in the number of inseminations per conception ($r$ = 0.019**).

Considering the effect of the cow's parity on the relationships between the LNSCC and the fertility, the strongest correlation was found with the duration of the CI, and, in addition, this correlation was stronger ($r$ = 0.059**) for the second calving cows. Ttabhe relationship between the LNSCC and SP remained at a similar level ($r$ = 0.017**) regardless of the cow's parity.

The coefficients of correlation between the LNSCC and the fertility of the cows, independently of the herd production level, assumed positive values and were mostly significant. The highest correlation (0.055**) between the LNSCC and the length of the CI was observed for herds producing 7000–9000 kg of milk. The relationships between the LNSCC and the length of SP in the herds producing 7000–9000 kg of milk were stronger ($r$ = 0.022**) than in the herds producing > 9000 kg ($r$ = 0.018**), while, in the lowest yielding herds, they were not significant. The relationships between the LNSCC and the SPC, in the case of herds producing 7000–9000 and > 9000 kg of milk, were slightly stronger than in the lowest producing herds.

Analysing the magnitude of the correlations between the LNSCC and the fertility parameters, with consideration of the stage of the lactation in which the first insemination took place, it was found that for the CI and SP, they were only significant up to 120 days in the milk (DIM), and their magnitude increased as the first insemination moved further away from the calving day. The information about the milk SCC in the successive lactation stages is considered less useful for the possible prediction of a cow's fertility. In the case of the SPC, significant relationships occurred up to day 150 of the lactation, but they were variable. The highest value ($r$ = 0.031) of the correlation coefficient was observed in the class of ≤ 60 in the milk (DIM), while, in the next periods, it was slightly alternating in its value.

The daily yield classes were connected with the differences in the coefficients of correlation between the LNSCC and the indicators of a cow's fertility. The relationships were stronger and stronger with the increasing daily yield classes (for the CI from $r$ = 0.039** to $r$ = 0.052**; for the SP from $r$ = 0.008 to $r$ = 0.033**). In the case of the SPC, the lowest value of the correlation coefficient ($r$ = 0.025**) was noted in the yield class of 20.1–30.0 kg ($r$ = 0.025**), the highest value ($r$ = 0.038**) in the yield class of 30.1–40.0 kg ($r$ = 0.038**), while, in the lowest and highest yield classes, the correlation values were similar ($r$ = 0.029** and $r$ = 0.030**, respectively).

The analysis of the relationships between the LNSCC and the length of the SP and SPC revealed that they were significant outside the winter/spring period, and slightly stronger relationships ($r$ = 0.027** and $r$ = 0.031**) were observed between September and November. The relationship between the LNSCC and the CI was ($r$ = 0.038**–0.030**) in the winter/spring period and approximately twofold in the summer/autumn period.

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Table 1. The effect of the udder health status on the fertility parameters of dairy cows

| | | Indicators of cow fertility | | |
|---|---|---|---|---|
| | | Number of days between consecutive calvings | Number of days between the first and successful insemination | Number of services required to conceive |
| Total | | 450 | 54.8 | 2.20 |
| Somatic cell count in 1 ml of milk | ≤ 200 000 | 452[ab] | 54.0[a] | 2.15[AB] |
| | 200 001–400 000 | 454 | 56.0 | 2.19 |
| | 400 001–1 000 000 | 456[a] | 57.3 | 2.24[A] |
| | > 1 000 000 | 456[b] | 58.1[a] | 2.26[B] |

The values differing significantly within a factor are marked with the same letters as [A,B] for $P \leq 0.01$ and [a,b] for $P \leq 0.05$

Table 2. The coefficients of correlation between the somatic cell count (LNSCC) in the milk and the reproductive parameters

| Parameters | | n | Number of days between consecutive calvings | Number of days between the first and successful insemination | Number of services required to conceive |
|---|---|---|---|---|---|
| Total | | 88 745 | 0.050** | 0.016** | 0.019** |
| Lactation number | 1 | 55 685 | 0.047** | 0.018** | 0.021** |
| | 2 | 33 060 | 0.059** | 0.017** | 0.018** |
| Herd production level (unit) | ≤ 7000 | 34 869 | 0.046** | 0.009 | 0.020** |
| | 7000–9000 | 36 708 | 0.055** | 0.022** | 0.024** |
| | > 9000 | 17 168 | 0.040** | 0.018* | 0.024** |
| Lactation period of first insemination (unit) | ≤ 60 | 35 022 | 0.015** | 0.021** | 0.031** |
| | 61–90 | 27 047 | 0.022** | 0.021** | 0.022** |
| | 91–120 | 15 199 | 0.026** | 0.022** | 0.026** |
| | 121–150 | 7638 | 0.021 | 0.018 | 0.024* |
| | 151–180 | 3839 | −0.004 | −0.004 | 0.021 |
| Daily productivity (kg/day) | ≤ 20 | 14 725 | 0.039** | 0.008 | 0.029** |
| | 20.1–30.0 | 40 219 | 0.048** | 0.020** | 0.025** |
| | 30.1–40.0 | 25 064 | 0.052** | 0.032** | 0.038** |
| | > 40 | 8737 | 0.052** | 0.033** | 0.030** |
| Season of first insemination | winter | 20 384 | 0.038** | 0.003 | 0.006 |
| | spring | 24 811 | 0.030** | 0.010 | 0.012 |
| | summer | 21 339 | 0.057** | 0.023** | 0.024** |
| | autumn | 22 211 | 0.072** | 0.027** | 0.031** |
| Number of cows in herd | ≤ 20 | 14 976 | 0.034** | −0.004 | 0.000 |
| | 21–50 | 32 270 | 0.046** | 0.004 | 0.001 |
| | 51–200 | 20 691 | 0.055** | 0.023** | 0.031** |
| | > 200 | 20 808 | 0.061** | 0.034** | 0.033** |

The significance was marked as $^{**}P \leq 0.01$, $^{*}P \leq 0.05$

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The herd size modified the coefficients of correlation between the LNSCC and the fertility parameters of the cows. In herds of ≤ 50 cows, the LNSCC was not significantly correlated to the length of the SP and the SPC, but the correlation was statistically confirmed in larger herds, assuming the highest values in herds of > 200 cows. The correlations between the LNSCC and the CI were significant for all the herd size classes, and the magnitude of these correlations increased with the increasing number of cows (from $r = 0.034^{**}$ to $r = 0.061^{**}$).

## DISCUSSION

Increasing attention has recently been given to udder inflammation in the context of its relationships with reproductive abnormalities (Skrzypek et al. 2007; Wolfenson et al. 2015). Pinedo et al. (2009), who accounted for the period before the first insemination, found that the in SCC's above 283 000/ml, it was paralleled by an increase in the SPC (by 0.49) and the lengthening of the RRP and the days open. In addition, an SCC above 283 000/ml during the period before the insemination was accompanied by an approximately 15% decrease in the first insemination success, compared to cows with an SCC below 283 000/ml. These findings agree with other authors (Miller et al. 2001; Rekik et al. 2008). A study with the Czech population of Holstein cows revealed that clinical mastitis had a significantly negative effect on the number of inseminations per conception, and that cows with two cases of clinical mastitis during lactation were characterised by higher SPC values (2.58) compared to the unaffected cows or cows that were affected once (SPC of 1.94 and 2.34, respectively) (Vacek et al. 2007). Also, in a Lithuanian study (Juozaitiene and Juozaitis 2005), the increase in the SCC caused fertility of the cows to decrease (CI, SPC) during the first three lactations. Likewise, Ahamadzadeh et al. (2009) showed significant differences between the least square means for the SPC between cows suffering from clinical mastitis and healthy cows (2.1 vs 1.6 inseminations). Also, Gunay and Gunay (2008) considered clinical mastitis as a factor negatively affecting fertility (the SPC in the affected groups to 2.1 and 3.4, compared to 1.8 in the control group). Similarly, Lomander et al. (2013) reported an increasing SCC (from below to above 200 000 cells/ml in a month) to cause a 60% decrease in the first insemination success and to increase the number of inseminations per conception (2.27 vs 1.76). In turn, Nguyen et al. (2011) showed that exceeding 200 000 somatic cells/ml in the milk had an adverse effect on the cow's fertility in Japan. Exceeding this limit decreased the conception rate and increased the days open, and exceeding 500 000 cells/ml was associated with a delay in the first ovulation. In this regard, it is interesting to note the results of Hertl et al. (2010), because clinical mastitis occurring more than 15 days before and more than 35 days after the insemination was not reported to have a statistically significant effect on the fertility, whatever the etiological agent involved. In turn, an udder inflammation between 14 days before and 35 days after insemination had a significant effect on the fertility and was more marked during the periods closest to the insemination, especially when they resulted from the presence of gram-positive microorganisms. The likelihood of insemination decreased during this period by as much as several dozen percent, and the highest decreases in the conception rate were associated with the gram-negative microorganisms found in the milk.

Our study showed that higher LNSCC values were associated with longer CI ones ($r = 0.050^{**}$) and SP ($r = 0.016^{**}$) as well as the SPC ($r = 0.019^{**}$). These results are consistent with the findings of Kadarmideen (2004), in which the phenotypic correlation values fluctuated around zero: between the LNSCC and the RRP, they were $r = 0.05$, and for the non-return rate, they were $r = -0.02$ and statistically significant ($P \leq 0.05$).

Our results, for the influence of the cow's parity on the magnitude of the correlations between the LNSCC and the fertility, correspond with the findings of Montaldo et al. (2010), who reported that the coefficient of correlation was higher for the second-calving cows ($r = 0.030$) compared to the first-calving cows ($r = 0.019$). In turn, Pritchard et al. (2013) showed almost identical values of the phenotypic correlations between the LNSCC and the CI (0.03 vs 0.04), the SPC (0.03 vs 0.02), the RRP (0.02 vs 0.03) and the non-return rate (0.02 vs −0.01) in the case of primiparous cows and the population of the first to third lactation cows.

Skrzypek et al. (2007), who analysed the effect of the somatic cell count on the cow's fertility observed no significant correlations between the LNSCC and the SPC, regardless of the period between the calv-

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ing and the first insemination. However, the authors pointed to a statistically significant relationship ($r$ = 0.12–0.14) between the LNSCC in the milk from the control milking preceding the insemination and the services per conception.

Overall, our results correspond with the observations of Hudson et al. (2012) that mastitis, both clinical and subclinical (measured by the milk somatic cell count), shows negative, but time-varying relationships with the reproductive performance of dairy cows.

The present study established that the increased SCC in the milk had an adverse effect on a cow's fertility (the SP and CI longer by about 11 and 4 days, the SPC greater by about 0.11). The values of the correlation coefficients between the LNSCC and the fertility indicators have changed, for example for the CI – the CI most changed depending on the season of the first insemination (spring $r$ = 0.030, winter $r$ = 0.072) then they also changed depending on the number of cows in the herd (≤ 20 $r$ = 0.034, > 200 $r$ = 0.061). It has been shown that monitoring the number of the somatic cells in the milk could contribute to improving the fertility of the cows in particular: the cows in the second lactation (for CI ($r$ = 0.059*)); in the herd production level of 7000–9000 kg of milk (for a CI ($r$ = 0.055**), an SP ($r$ = 0.022**) and an SPC ($r$ = 0.024**)).

The magnitude of these correlations varied within the classes of the factors such as the daily production level, the age of the cow's lactation number, the season of the first insemination, the herd production level, and the herd size. It appears that the somatic cell count results obtained from the periodic milk recording, considered as an indirect measurement of the udder health and used when deciding on a mastitis treatment, could be a useful tool for the control of fertility in cows.

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