The interrelation of the level of somatic cells in milk at the end of lactation with fertility and milk yield of Ayrshire cows in the conditions of the European North of Russia

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Abstract. The work studies the influence of the somatic cell level in milk in the last months of lactation on the indices of reproduction and productivity of cows in the subsequent lactation. To study this problem, we used a database of a herd of highly productive purebred Ayrshire cattle of a large farm in the North of Russia. The average milk yield was 8000 kg of milk. The indices of reproductive capacity of cows (indifference period, insemination period, service period, conception index, conception rate after the first insemination, early embryonic mortality) were analyzed. The change in the number of somatic cells in dynamics during the whole lactation in cows of different ages was studied. It has been established that the number of somatic cells in milk can serve as an indirect assessment of the udder condition. Our study revealed a complex, ambiguous relationship between the level of somatic cells and reproductive qualities. Inflammation of the udder in the last months of lactation before the dry period can increase the risk of decline of reproductive indicators in the postpartum period, increasing the degree of embryonic mortality. It has been determined that first-calf heifers are less likely to suffer from udder diseases. However, the negative impact of mastitis on subsequent fertility in young animals is higher than in mature cows.

1 Introduction

Reduced fertility of cows is an important problem in intensive milk production. Impaired reproductive functions of cows are one of the most common reasons for culling and shortening the productive life of cows. Reproductive qualities of cattle are interconnected with many factors, including the level of productivity and resistance to diseases. Increased milk productivity is often accompanied by a decrease in the immunity of cows, which causes increased susceptibility to infectious diseases, such as mastitis. Mastitis is currently the most common disease of dairy cows. Many studies establish the effect of inflammatory processes in the mammary gland on milk productivity, contents and quality of milk. There is a connection between mastitis and the reproductive system of animals. The effect of mastitis on the fertility of cows in different periods of lactation is studied, but the results of

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the research are contradictory. According to some authors, inflammation in subclinical mastitis may be insignificant and not cause follicular growth disorders [1]. There are substantiated assumptions about the effect of mastitis in the period immediately after calving and before the first insemination, during insemination and at the beginning of embryo development. Reproductive functions are no less susceptible to the influence of infection during the dry period, when the process of oocyte maturation in the ovary can be disrupted by inflammatory processes in the udder [2]. It is relevant to study the effect of inflammatory processes in the udder at the end of lactation on the fertility of cows after calving.

The main diagnostic method for the subclinical form of mastitis, which is most common in dairy herds, is the determination of the somatic cell count (SCC) in milk [3]. Therefore, SCC can simultaneously be an indirect indicator of the state of reproductive function in cows. However, it should be taken into account that the somatic cells level in milk in healthy cows also depends on a wide range of factors. For example, feeding errors, metabolic disorders, ketosis can be accompanied by an increase of SCC in milk.

2 Material and methods

The study was conducted on a herd of purebred Ayrshire cattle (Republic of Karelia, Russia). The average milk yield per forage cow during the study period was over 8,000 kg of milk. The enterprise uses industrial milk production technology with loose housing, uniform feeding throughout the year, automatic feed distribution and milking in a milking parlor using DeLaval equipment.

In our work we studied the following indices of cow reproductive capacity: the period from calving to the first insemination (days) – the indifference period (IP), the period from the first to fruitful insemination (days) – the period of insemination (PI), the period from calving to fruitful insemination (days) – the service period (SP), fertility after the first insemination (%) – conception rate (CR), number of inseminations per conception (times) – conception index (CI), early embryonic mortality (%) – EEM. Among the productivity indicators we took into account milk yield for the first 305 days of lactation (MY, kg) and average daily milk yield of cows (DMY, kg/day).

The study used the database and the enterprise's zootechnical record documents with records of 1,310 cows of the first, 1,047 of the second and 686 of the third lactation. Fertility and productivity indicators were collected from cows on the basis of data on 3,043 completed lactations. The method of accounting for extended intervals (25-35 days) between adjacent inseminations was used to determine early embryonic mortality [4]. The frequency of EEM was determine as the percentage of the number of extended intervals to the total number of cows examined.

The study included cows without reproductive system pathologies

The somatic cell count (SCC) in each cow's milk was determined in a specialized laboratory using infrared spectrometry at least 5 times per lactation during the first three lactations in 2016-2018. All cows were divided into gradations taking into account the somatic cell count in milk.

On the basis of the somatic cell count (SCC), we conducted an indirect assessment of the mammary gland condition. The following groups of cows were identified: healthy - SCC<200 thousand/ml; sick - SCC≥500 thousand/ml. Cows with a value of 200≤SCC<500 thousand/ml were classified as conditionally healthy with an average degree of udder infection. To exclude the effect of udder diseases on the fertility of cows in the current lactation, we selected only animals that had been healthy for 3 months after calving.

3 Results

The studied fertility indices of cows were typical for cows with a milk yield of 7200–8200 kg per lactation. For the entire herd, the indifference period (IP) lasted 89.5–91.8 days, the service period (SP) – 130.9–134.7 days. The insemination index (CI) was 1.84–1.91, the conception rate after the first insemination (CR) – 48.5–51.3%. The age of the animals did not have a significant effect on the reproductive capacity indices. They were almost the same from the first to the third lactation in cows.

At the same time, the concentration of somatic cells in milk increases slightly with age ($P<0.001$) from 103.8 thousand/ml in first-calf heifers to 150.3 thousand/ml in the 2nd lactation and most significantly by the 3rd lactation – up to 192.0 thousand/ml.

During lactation, the number of somatic cells in milk also changes. The lowest number of somatic cells is typical for the period of increasing milk productivity, i.e. during the first 2-3 months after calving, in cows of all ages. The average number of somatic cells increases towards the end of lactation. Age differences are obvious here. Thus, during the first 3 months of the 1st lactation, the number of somatic cells averages 57.6–80.7 thousand/ml, during the last 3 months it makes 110.3–141.4 thousand/ml, which corresponds to a healthy udder. At the end of the 2nd lactation, the average number of somatic cells was 198.4–227.1 thousand/ml, and in the 3rd lactation – 225.2–305.6 thousand/ml. This is significantly higher ($P<0.05$) than in young cows. Increased SCC is typical in late lactation but may also indicate mastitis in dairy cows.

The repeatability of the SCC level determined before dry period in the 1st and after calving in the 2nd lactation is +0.187 ($P<0.001$), for the corresponding periods of the 2nd and 3rd lactations it is +0.139 ($P<0.05$).

It is generally accepted that the concentration of SCC above 200 thousand/ml indicates udder damage by subclinical mastitis [5]. Over the entire study period, we recorded increased SCC in 8.8% of milk samples from first-calf heifers, in cows in the 2nd and 3rd lactations - 13.6% and 17.5%, respectively ($P < 0.001$). The number of cows with an increased SCC concentration during 6 months of the first lactation was 6.2–9.6%, in 7–10 months their share exceeded 10% (10.0–12.4%). Among cows in the 2nd lactation, already in the 4th–7th months there were 10.3–15.3% of cows with SCC over 200 thousand/ml, and in the pre-dry period their number reached 20.3–23.3%. High concentrations of somatic cells were detected in 22.0–29.3% of mature cows at 7–9 months, and 36% at 10 months.

We studied the influence of the average level of SCC, as well as the excess of the critical level of SCC (200 thousand/ml) in the last months of the previous lactation on the fertility of cows. The cows were tested for mastitis for 3 months before calving and 3 months after it. We excluded the cows with manifestations of subclinical mastitis for 3 months after calving, i.e. during the indifference period, although the farm carries out universal udder sanitation during the dry period as a preventive measure against mastitis. Thus, the study was conducted on the basis of data from 394 heads in adjacent 1-2 lactations and 270 heads in 2-3 lactations.

The largest number of first-calf heifers had a characteristically low average SCC value in the last 3 months before dry-off. An average SCC of less than 200 thousand/ml was observed in 352 cows (89.3%), including 290 cows (73.6%) whose value did not exceed 100 thousand/ml (Table 1). No significant effect of the average SCC in the last months of lactation on the average daily milk yield or the main fertility indices was found.

The considered reproduction periods have some peculiarities of their duration. The first insemination of cows at the farm is carried out mainly in the 2nd-3rd heat, therefore the IP can largely be determined not only by the condition of the animal, but also by specialists. It is 88.9 days (i.e. about three months) and changes little depending on the gradations of the SCC. The service period is an important indicator determining the output of calves during

the year. In our study, the IP of cows in the 2nd lactation averaged 130.6 days. In the groups with a healthy udder, the period was 131.6-133.4 days, which is typical for highly productive cows. The duration of the period from the first to fruitful insemination (PI) in most cows (1st, 2nd, 5th grades) is 42.4-45.4 days, i.e. 2 cycles. In cows classified as conditionally healthy (3rd and 4th grades, 200≤SCC<400 thousand/ml), PI is on average 20.7-22.4 days, or one cycle. In these groups, the CI values are relatively low (1.57-1.59), and the CR values are high (52.9-57.1%).

Table 1. Fertility indicators of cows in the 2nd lactation depending on average SCC during the last 3 months of the pervious lactation.

Indicators	Total for the group	Graduations by SCC for the entire herd, thousand/ml					
		less than 100	100–199	200–299	300–399	400–499	500 and more
Number of cows	394	290	62	17	7	7	11
SCC in 8-10 months of the 1st lactation, thousand/ml	102.5±9.5	39.6±1.4	139.7±3.5	235.6±6.7	349.4±12.0	455.9±13.2	961.1±156.5
SCC in 1-3 months of the 2nd lactation	47.3±3.8	41.5±4.1	48.8±8.3	77.0±24.2	105.2±52.4	77.9±36.4	88.9±21.2
DMY in 1-3 months of 2nd lactation, kg/day	35.4±0.3	35.2±0.4	35.9±0.6	37.4±1.5	34.1±1.1	36.2±1.0	34.6±2.0
IP, days	88.9±1.9	89.2±2.2	90.1±5.0	93.2±8.5	74.4±11.9	68.3±8.7	88.6±12.6
PI, days	41.7±2.8	42.4±3.3	43.4±6.9	20.7*±8.3	22.4±10.9	45.4±21.1	57.8±17.7
SP, days	130.6±3.3	131.6±3.9	133.4±8.6	113.9±12.7	96.9**±10.0	113.7±24.5	146.5±17.7
CI	1.90±0.05	1.88±0.06	2.02±0.15	1.59±0.19	1.57±0.30	1.86±0.26	2.27±0.38
CR, %	44.9	45.5	41.9	52.9	57.1	28.6	36.4
EEM, %	9.6	7.6	12.9	11.8	28.6*	14.3	27.3*

Note: Reliability compared to the gradation of SCC<100 thousand/ml: * P<0.05; ** P<0.01

The insemination period (IP), service period (SP) and conception index (CI) increase in the group with the SCC of 500 thousand/ml and more compared to the 1st gradation by 15.4 and 14.9 days, 0.39 times, respectively. In the gradations by SCC of 400 thousand/ml and more, the conception rate (CR) decreased to 28.6–36.4% against 45.5–57.1% in the previous groups. In cows with the SCC of 349.4 and 961.1 thousand/ml, the EEM reached 28.6 and 27.3%, respectively, which significantly exceeds the indicator of cows with an average SCC of 39.6 thousand/ml (P<0.05).

When analyzing reproductive capacity and milk yield, we divided the cows into two groups by the number of somatic cells in the last three months of lactation (Table 2). In 335 first-calf heifers (85.0%), SCC never exceeded 200 thousand/ml at the end of lactation before dry period, which indicates a consistently healthy udder in these animals. When registering an increased SCC (200 thousand/ml or more), the cows were considered problematic concerning the health of the udder. The average SCC in this group was 387.0 thousand/ml. No differences were found between these groups by the main indicators of reproductive capacity, with the exception of EEM. In the second group, EEM increased significantly and reached 17.0% versus 8.4% in healthy cows (P<0.05). Similar results were obtained when taking into account the results of milk analysis only in the month preceding dry period.

Table 2. Fertility indicators of cows in the 2nd lactation depending of the occurrence of elevated SCC levels from the 8th to the 10th month of the previous lactation.

Indicators	Total for the group	Graduations by SCC for the entire group, thousand/ml	
		less than 200	200 and more
Number of cows	394	335	59
SCC in 8-10 months of the 1st lactation, thousand/ml	102.5±9.5	52.3±2.2	387.0±47.5
SCC in 1-3 months of the 2nd lactation	47.3±3.8	42.4±3.8	75.5±12.0
DMY of 1-3 months of 2nd lactation, kg/day	35.4±0.3	35.3±0.3	35.9±0.7
IP, days	88.9±1.9	89.4±2.1	86.2±4.8
PI, days	41.7±2.8	42.5±3.1	37.3±6.4
SP, Days	130.6±3.3	131.9±3.7	123.5±7.7
CI	1.90±0.05	1.90±0.06	1.88±0.13
CR, %	44.9	45.4	42.4
EEM, %	9.6	8.4	17.0*

Note: * P<0.05

The analysis of the fertility indices of cows in the 3rd lactation depending on the level of the SCC at the end of the previous (2nd) lactation is presented in Figure 1. There was a tendency for the CI to increase from 1.94–1.90 in groups of cows with the SCC less than 200 thousand/ml to 2.38–2.14 with an average SCC of 300–499 thousand/ml. At the same time, the CR decreased from 51.7–52.9% to 38.5–28.6%. We noted an increase in early embryonic mortality to 23.5%. However, unlike young cows, in full-grown animals the increase in SCC is accompanied by a significant decrease in EEM (up to 4.8%).

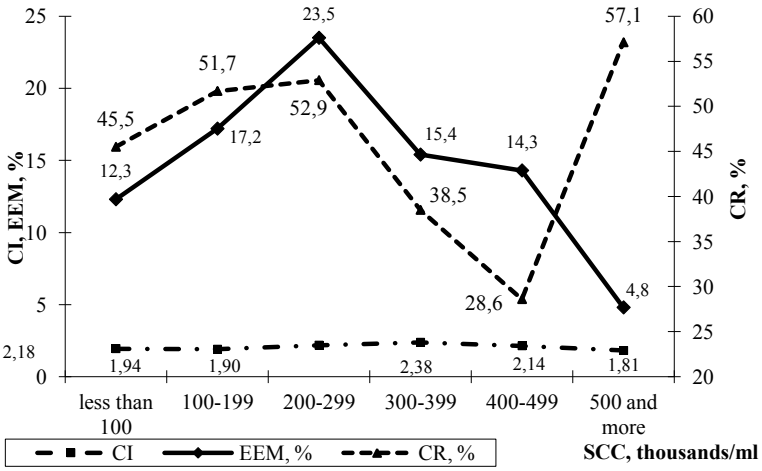

Fig. 1. Fertility indicators of cows in the 3rd lactation depending on average SCC during the last 3 months of the previous (2nd) lactation.

4 Discussion

Our study examined the relationship between mammary gland disease in the period preceding dry period and cow fertility in the following lactation. Periodic monitoring of the somatic cell count in milk can serve as an indirect assessment of mammary gland health

and help improve cow fertility, which is also confirmed by other studies [6]. The degree of influence of mastitis on cow fertility depends on the level of herd productivity, cow age and other factors, but is always negative [7].

Much attention is usually paid to udder health in the post-calving period. However, udder inflammation in the last months of lactation and during the dry period can increase the risk of gynecological complications in the postpartum period [8-9]. They often manifest themselves in retained placenta and metritis. An increase in the SCC can also negatively affect the fertility of cows [10]. Quite significant damage is caused by termination of pregnancy at different stages, which is manifested in early embryonic death and abortions. At the same time, if abortions are identified accurately enough, it is quite difficult to assess embryonic mortality in the early stages of pregnancy (up to 40 days) [4]. Meanwhile, the death of embryos in the early stages of development (EEM) is one of the reasons for the low fertility of cows. In our study embryo mortality ranged from 7.6% to 27.3-28.6% depending on the health of the cows' udders. According to other researchers, it can vary within 5-40% and higher [11].

First-calf heifers are less susceptible to udder disease, which is confirmed by other authors [1]. However, the negative impact of mastitis on subsequent fertility is higher in young animals than in adult cows.

5 Conclusion

Our study established that somatic cell count influences reproductive function.

In our opinion, the first insemination at a fairly late time (3rd heat, IP about 90 days) was performed upon completion of the involution of the reproductive system of highly productive cows. Therefore, against the background of healthy reproductive organs and mammary gland in the post-calving period, we established no reliable effect of the level of SCC in the pre-calving period on the duration of indifference period, period of insemination, and service period.

The effect of the SCC is most pronounced on the fertility of cows and embryo development. Cows with a healthy udder in the previous lactation were more likely to become pregnant after the first insemination, had a lower insemination index and a lower level of early embryonic mortality. Prevention of mastitis in the last months of lactation and during the dry period is important for maintaining the reproductive capacity of cows. We have revealed a complex, ambiguous relationship between the SCC level and reproductive qualities, which requires further study.

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