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Increase in reproductive ability of high-producing cows, and qualitative parameters of their offspring, under conditions of intensive milk production

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ABSTRACT

Objective: To study the methods of increasing the reproductive qualities and indices of viability in the offspring of Holstein cows under conditions of intensive milk production.

Methods: Studies were conducted on 3 groups of Holstein cows with 30 heads in each group. Animals of the experimental groups had a different length physiological period. The study focused on experimental groups of animals: the reproductive indicators, the viability of newborn calves, and their growth rate. All the digital materials of the experimental data were processed by the method of variation statistics for the significance of the difference of the compared parameters using the Student's criterion, adopted in biology and zootechnics.

Results: Studies found that reduction of the duration of the service period, along with a simultaneous increase in the inter-lactation period to 80–90 days, increased the reproductive capacity of the cows, and enhances the viability of the offspring compared with their peers.

Conclusions: The study revealed the optimal duration of the physiological periods in high-producing cows under conditions of intensive milk production technology.

1. Introduction

In recent years, both local and international studies have found that increase in milk productivity negatively affects the reproductive qualities of high-producing cows. However, in the literature, insufficient information exists regarding the relationship between the reproductive capacity of cows and the duration of various physiological periods. The optimization of the duration of these physiological periods in cows (*e.g.*, the inter-lactation, lactation, and service periods) ensures a metabolic normal level, thereby contributing not only to an increase in milk production, but also to an increase in the reproductive capacity of cows and an increase in their productive longevity. An increase in the economic use of high-producing cows is an important task worldwide[1–6].

The reconstruction of farms for intensive milk production technology has been performed, and modern technology is implemented, which provides the loose keeping of cows, milking cows in milking parlors, the use of modern equipment, devices, and computerization of all production processes. Due to the lack of high-producing livestock, an imported breed of cattle (Holstein) has been brought to high-technology complexes. However, with the transition to a more intensive milk production technology, cattle farmers have faced difficulties. One of these difficulties has been the low yield of calves per 100 cows; the calves obtained also have low viability, which inhibits the reproduction of the herd[1,7].

Various factors of nonspecific and specific protection of animals

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during pregnancy are the main parameters that ensure the resistance of a newborn's organism to unfavorable environmental effects during the exploitation of animals. In addition, the development of methods for testing enables the determination of the ability of the body to resist such influences and make practical economic decisions[6,8–10]. The development of new principles for solving technological issues related to the lactation, inter-lactation, and service periods in cows, and the rearing of young animals should be aimed at increasing the number of animals with high genetic potential[3,8,11].

At present, reproductive qualities, along with productivity, are considered when evaluating the reproduction of cows. However, in the future, the importance of various reproduction aspects in breeding programs is expected to increase, which will require new methods for predicting reproductive potential. But according to several authors, genetic selection for fertility cannot compensate for the poor organization of reproduction[1,4,8,12].

The question of the relationship between the duration of the period from calving to fertilization and milk yield has more often been considered in the opposite aspect, that is, the influence of the duration of the service period on the productivity of cows. This relationship is due to the effect of pregnancy on lactation. It is well known that, from the fifth month of pregnancy, a more intensive growth of the fetus occurs and, simultaneously, a noticeable decrease in milk yield occurs. Thus, the earlier the cow is fertilized, the earlier the pregnancy causes an effect on the secretion of milk, and lactation will be shorter[1,6,12].

Gnidina *et al*[2] and Dias and Allaire[4] have indicated that the level of productivity significantly affects the duration of sexual cycling after calving, and every additional 3.8 kg of milk per day delays the first stage of the initiation of the sexual cycle by 1.5 days. This parameter was extended by 5–10 days with an increase in milk yield per 1 000 kg for lactation.

On the contrary, Abylkasymov *et al*[1] determined the functional status of the ovaries in terms of the content of progesterone in milk, and concluded that the milk yield does not influence the timing of the restoration of sexual cycles.

Although there is no agreement on the influence of milk yield on reproductive function, many studies have noted a decrease in fertility with increasing milk yield and number of calves. In other words, a set of measures aimed at increasing productivity does not have a positive effect on the reproductive capacity of cows[2,9].

Under conditions of intensive dairy cattle breeding in high-producing cows, a negative correlation has been found between high milk productivity and reproductive capacity[2,4,10]. Convincing data has been provided on the negative effects of a high milk yield on the rate of fertilization in cows. In these studies, this effect was manifested when the level of the productivity of cows was 4 000 kg and higher. Indeed, with an increase in milk yield by 1 000 kg, the fertilization rate from the first insemination decreased from 65.3% to 54.6%, a difference of 10.7%. A similar pattern has been observed in studies of the relationship between fertilization rates and the productivity of cows in the three leading breeding farms of the Leningrad Region. In these farms, a decrease in fertilization rates by 6%–13% per 1 000 kg of milk was revealed. The most intensive decrease in the fertilization rate was also observed with a milk yield

of 4 000 kg. The productivity boundary, where the fertilization index is deteriorated under favorable conditions of feeding and the management of animals, is discussed in many studies. The results obtained by several authors show that a decrease in fertility rates with increased productivity occurs up to the achievement of a certain level of milk yield[7,11,12].

The fertility rate of cows can also be characterized by the number of inseminations required for fertilization, which is termed the insemination index. An increase in this parameter, along with an increase in the lactation level in cows, has been described in many studies[2,10,13].

According to some authors, the level of milk productivity affects the morphofunctional status of newborn calves. The authors note that the duration of the physiological periods (*i.e.*, the term of insemination and the duration of the inter-lactation and lactation periods) should be determined by the production field of the farm and the level of the dairy productivity of the cows. The future productivity is determined by such factors as the course of labor, the morphofunctional status of a calf at birth and during the early period of life, and also the intensity of their growth to the period of physiological maturation[6,8,11]. Because of these factors, the study of techniques for optimizing milk production technology, along with the reproductive qualities of cows and obtaining viable offspring, is necessary.

In order to better understand this problem of reproduction with an increase in the dairy productivity of cows, and to obtain viable rearing young animals, it is necessary to make changes in the technology of cow management, depending on their production field, which may provide a significant increase in the yield of rearing heifers with a high potential for milk productivity. Through methods of biological and technological correction, the optimization of lactation and reproduction can be achieved. At present, this problem is urgent, as it affects the system of obtaining and rearing young animals from high-producing dam cows. Thus, the solution of this issue for dairy farms is an important scientific and practical task.

This study aimed to increase the reproductive qualities and indices of viability of offspring in Holstein cows under conditions of intensive milk production. Accordingly, the following tasks were set: 1) to study the reproductive parameters of cows depending on the duration of their physiological periods (*i.e.*, lactation, inter-lactation); 2) to determine the morphofunctional status of newborn calves depending on the duration of the physiological periods of their mothers; 3) to study the intensity of heifer growth in study groups up to 18 months of age.

2. Materials and methods

This study was performed on cows of the Holstein breed under conditions of the state unitary enterprise. The study of the effect of the duration of physiological periods on the reproductive qualities of dam cows, the morphofunctional status of newborn calves and their growth and development (heifers) was performed in two stages.

To form the study groups of animals, biometric processing of the indices of the duration of the service period, lactation, and inter-

lactation in cows of the milk herd were performed. Three groups (control group, study group 1, study group 2) of animals composed of 30 heads each were formed from the number of pregnant cows (3–4 months of pregnancy). The duration of lactation was established by adjusting the duration of the inter-lactation period, which was performed using a one-time method of cow drying off. The duration of lactation in the control group of animals was (372.80 ± 10.30) d, the duration of the inter-lactation period was (59.60 ± 4.20) d, and the duration of the service period was (162.00 ± 9.16) d. In study group 1, the lactation duration was (310.70 ± 12.00) d; the inter-lactation period lasted for (80.50 ± 2.50) d, and the service period was (120.20 ± 8.13) d. In study group 2, the duration of lactation was (300.80 ± 7.18) d, the inter-lactation period was (90.80 ± 2.40) d, and the service period lasted for (120.60 ± 12.14) d. The milk productivity of the study groups of cows was more than 7 000 kg of milk.

For the first stage of the study in the study groups of animals, the following parameters were studied: the course of labor (in 5 heads from each group) and the postpartum period, the viability of newborn calves, and the duration of the uterus involution. The assessment of the viability of calves was performed according to the method of Krishtoforova[14].

For the second stage of the work, the effect of the duration of the physiological periods on the restoration of the reproductive function of cows after calving was studied (the duration of manifestation of the sexual cycle after labor, the duration of the service period, fertilization in the first and subsequent estrus, and the insemination index), and the growth rate of heifers of the study group was examined to 18 months of age.

For this purpose, three groups of animals of 14 calves each were formed from the calves obtained from calving, in accordance with their belonging to the parent group. The dynamics of the live weight of the heifers was studied by individual weighing at the end of each calendar month on an electronic “Prirost” scale with an accuracy of 0.001 kg.

All the digital material of the experimental data was processed by the method of variation statistics for the significance of the difference of the compared parameters using the Student’s criterion, adopted in biology and zootechnics, using MS Excel. Differences were significant as $P < 0.05$. The study protocol was approved by the Institutional Ethics Committee of the Samara State Agricultural Academy (protocol number No. 1, 24 January 2018).

3. Results

The study showed that the duration of the course of labor in the groups of animals was not identical. In the control group, the course of labor amounted to (7.42 ± 1.18) h, while in study group 1 and 2, it was (5.45 ± 0.92) h and (5.20 ± 1.04) h, respectively. In determining the duration of labor, the time from the moment of the first sign of labor manifested until the separation of the placenta was counted.

The duration of labor correlated with the duration of the lactation period and the period of inter-lactation. In study group 1 and 2, the duration of labor was accordingly less by 1.97 and 2.22 h when compared with the control group. This may be because of a better morphological and functional state of the genital organs of the cows in study group 1 and 2.

The duration of the separation of the placenta in the groups was also different. In the control group the duration was (7.20 ± 1.07) h, while in study group 1 and 2, the duration was (3.78 ± 0.45) h and (3.05 ± 0.78) h, respectively.

The duration of lochia in the control group lasted for (15.20 ± 2.79) d, while in study group 1 and 2, it was (13.50 ± 1.80) d and (12.00 ± 1.04) d, respectively. A rectal examination of the ovaries and uterus (the state of the cervix, the consistency of the uterine horns, their size, the absence of excretions during uterine massage, and the absence of a yellow body in the ovaries) determined the end of uterus involution in the study groups of animals. The duration of the end of uterine involution, according to rectal examinations, in the control group was (32.00 ± 4.20) d, while in study group 1 and 2, it was (24.60 ± 1.62) d and (20.80 ± 1.13) d, respectively.

In animals of the control group that had an extended service period, along with prolonged lactation and 60 days of the inter-lactation period, the first sexual cycle was observed. In study group 1 and 2, the first sexual cycle was found in Table 1. This difference was statistically significant ($P < 0.05$).

The efficiency of insemination was also different and depended on the group of animals. Table 1 showed the fertility rate of cows in the first insemination, second insemination, third insemination as well as the percentage of pregnant cows after four inseminations in control group, study group 1, and study group 2. The interval between sexual cycles in the control group indicated the irregularity of the sexual cycles compared to the animals of study groups 1 and 2, where single cases of irregularity of the sexual cycles were noted. The duration of the service period in the cows of study group 1 and

Table 1
Reproductive qualities of cows, depending on duration of physiological periods.

Parameter	Control (n=30)	Study group 1(n=30)	Study group 2 (n=30)
Manifestation of the first sexual cycle after calving (days)	41.80±3.85 [†]	27.30±1.86 ^{**†}	27.80±1.98 ^{**†}
Fertility rate [n(%)]			
First insemination	13(43.3)	17(56.7)	16(53.3)
Second insemination	4(13.3)	7(23.3)	8(26.6)
Third insemination	6(20.0)	5(16.7)	3(10.0)
After the fourth and subsequent inseminations	2(6.7)	1(3.3)	2(6.7)
Total inseminated	25(83.3)	30(100.0)	29(96.6)
Interval between sexual cycles (days)	30.40±2.85 [†]	21.10±1.75 [†]	22.10±2.16 [†]
Service period (days)	146.40±12.60 [†]	113.90±7.18 ^{**†}	126.40±9.13 ^{**†}

* $P < 0.05$.

** $P < 0.01$, compared with control group.

†Data shown as mean ±SD.

2, in which the duration of the inter-lactation period was 80 and 90 days, respectively, amounted to 113.9 and 126.4 days, respectively. This was 32.5 and 20.0 days less than that found in cows from the group with an inter-lactation period of 60.0 days, respectively.

The definition of the morphological and functional status of neonatal calves enabled one to perform contemporary and purposeful correction of intrauterine development, using technological methods of feeding and management, and the production maintenance of animals (lactation).

According to the test system, the assessment of the viability of calves showed that the duration of the physiological periods (*i.e.*, lactation, inter-lactation, and service periods) affected the calves' viability gradients. From the data in Table 2, it was seen that, in the calves of the control group, the time of the implementation of the standing posture they were statistically significantly inferior to their peers, and this period was longer for them, amounting to 25.0 min, which was 4.3 and 3.1 min longer than in calves of study group 1 and 2, respectively. The time of manifestation of the sucking reflex in the control group of calves was 32.4 min, which was 6.7 and 7.6 min more than their peers of study group 1 and 2, respectively.

In addition, the study revealed the distance between the ventral end of the last rib and the frontal line of the shoulder joint, as well as the distance between the tip of the tail and the apex of the calcaneal tuber, in study group 1 and 2 was less by 33.0% and 81.0% than that observed in calves obtained from dam cows with prolonged lactation (352.8 d) and an inter-lactation period of 59.6 d, respectively. A large distance between the last rib and the frontal line of the shoulder joint, between the tip of the tail and the apex of the calcaneal tuber, as well as a smaller number of incisive teeth in calves of the control group was 1.0 pieces less than in the animals of study group 1 and 2. The number of leukocytes and erythrocytes in animals of study group 1 and 2 was significantly higher than in control group calves. The live weight at birth of calves of study group 1 and 2 was 3.1 and 2.9 kg greater respectively than in calves obtained from the control group cows. In the control group, one case of calf death (male) was noted within 18 h after birth (Table 2).

Table 2

Viability of calves at birth.

Parameter	Control	Study group 1	Study group 2
Time of implementation of standing posture (min)	25.00 ± 2.15	21.70 ± 1.42**	21.90 ± 1.06**
Time of manifestation of the sucking reflex (min)	32.40 ± 4.08	25.70 ± 2.05*	24.80 ± 1.78*
Number of incisive teeth (pieces)	6.80 ± 0.27	7.80 ± 0.20	7.80 ± 0.67
Distance between the last rib and the frontal line of the shoulder joint (cm)	6.80 ± 0.14	5.10 ± 0.22*	5.00 ± 0.18
Distance between the tip of the tail and the apex of the calcaneal tuber (cm)	7.60 ± 0.40	4.20 ± 0.18**	3.90 ± 0.21***
Number of white blood cells (thousand/ μ L)	6.80 ± 0.35	7.50 ± 0.20**	7.40 ± 0.35**
Number of red blood cells (thousand/ μ L)	6.70 ± 0.16	7.20 ± 0.23*	7.20 ± 0.19*
Live weight (kg)	33.80 ± 1.67	36.90 ± 1.58	36.70 ± 1.40

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$, compared with control group.

Data showed Mean \pm SD.

Table 3

Changes of live weight of heifers (Mean \pm SD) (kg).

Groups	Newborn	1 month	3 months	6 months	12 months	18 months	Total gain
Control	33.80 ± 1.21	50.40 ± 2.52	86.70 ± 2.45	148.30 ± 3.86	239.00 ± 4.16	368.30 ± 5.74	334.50 ± 4.62
Study group 1	36.90 ± 0.36	61.10 ± 1.32	111.30 ± 1.79	175.00 ± 2.18	276.20 ± 3.05*	417.50 ± 3.78*	388.60 ± 5.13
Study group 2	36.70 ± 0.40	59.80 ± 1.12	107.80 ± 2.03	173.80 ± 3.44	275.20 ± 2.60*	415.90 ± 2.87*	379.20 ± 4.76

* $P < 0.05$, compared with control group.

The preservation of calves obtained from the dam cows of the control group at one month of age was 80.0%, which is 20.0% less than in study group 1 and 2. The change in the live weight of the study groups of animals in different periods of ontogenesis was presented in Table 3. The animals of the control group were inferior in terms of their growth intensity when compared with the animals of study group 1 and 2, particularly after 3 months of age. Thus, at 3 months of age, the animals of the control group had a live weight of 86.70 kg, which was 24.00 kg less than those in study group 1 and 21.10 kg less than those in study group 2. The difference in the live weight of heifers obtained from cows with different durations of physiological periods increased with age. The live weight of 18-month-old heifers from dam cows that had an inter-lactation period of 80 or 90 days was 417.50 and 415.90 kg, respectively, which was 49.20 and 47.60 kg more than heifers obtained from dam cows with a duration of the inter-lactation period of 60.0 days, respectively.

4. Discussion

Reproductive capacity of the cows, under conditions of intensive milk production depends on the duration of physiological periods. Duration of physiological periods in highly productive cows: the service period was 120 days; the interlactation period was 80.5 days; and the lactation period was 310 days provide a reduction in the duration of labor of 1.97 h compared to the control group of cows, which is the result of the best morphofunctional state of the genital organs in the cows of this group before delivery. The existence of significant reproductive problems is indicated by O'Hara *et al*[3]. The authors note that the level of feeding is not always the reason of low indices of reproductive function of cows. The duration of delivery correlates with the duration of lactation and inter-lactation period from the indices of which depends the preparedness of animals to calving, and also has an influence on reproductive qualities of animals.

The study reveals that for the same productivity in cows of the

studied groups of 7 000 kg or more, the restoration of reproductive ability has significant differences. The less service period and a longer period of inter-lactation period increase the productivity qualities of cows, and this may be a result of fact that animals (control group) with an extended service period increases the duration of lactation and animal within 60 days of the inter-lactation period did not have time to recover and prepare for calving. The increase of viability of calves from the cows of the experimental groups is the result of the positive effect of the increase in the dry period to 80.5 days, which is also confirmed by a significant increase in the number of erythrocytes and leukocytes in the calves of the experimental groups compared with the control.

The present study data are consistent with the results obtained by Krishtoforova[14] that the decline in the viability of calves is a consequence of their underdevelopment during the embryonic period due to the severe exploitation of the dam cows. The intensity of growth of the studied groups of heifers depends on different duration of physiological periods in their mothers. The reduced growth rate in heifers of the control group is confirmed by lower levels of the criterion for assessing the viability of calves at birth compared with their peers from study group 1 and 2. At 18 months of age, heifers with optimal parameters of physiological periods have a live weight 417.50 kg, which is 49.20 kg more than their peers in the control group. The study data are consistent with the results of Dias and Allaire[4] indicating that the impaired development in the fetal period reduces average daily gain of animals at 8%-12%.

Based on the studies conducted, it revealed that the optimal duration of the physiological periods in high-producing cows under conditions of intensive milk production technology is as follows: the service period was 120 days; the inter-lactation period was 80.5 days; and the lactation period was 310 days. The stated parameters of the duration of physiological periods in cows with a milk production level of 7 000 kg and more contribute to an increase in the reproductive capacity of the cows (reduction in the duration of labor, postpartum period, restoration of reproductive function after calving, and fertilization rate), and an increase in the viability of calves (preservation) and growth rate (live weight at 18 months of age).

Implementation of the proposed biotechnological methods can increase the yield of calves by 20%–30%, safety by 15%–20%, and growth rate by 12%–14%, which will create prerequisites for increasing the number and quality of rearing young animals, while maintaining and improving the reproductive function of cows. These parameters will ultimately ensure the imported substitution of dairy cattle.

These studies differ from other scientific papers devoted to improving the efficiency of dairy cattle breeding in that the innovative methods proposed by the authors resolved the contradictions between the level of dairy productivity and the reproductive qualities of cows. In this study, the level of dairy productivity was optimized and the individual characteristics of animals were taken into account, which is absent in the technologies used for the reproduction in Russia and abroad. Implementation of the proposed research results will provide an increase in the yield of calves and their preservation, while increasing the reproductive ability of heifers-daughters and

their growth and development intensity. The obtained data can be used by local and international scientists to develop and improve the technology of the reproduction of dairy cattle, ensuring an increase in milk productivity and the period of economic use of cows.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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