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ORIGINAL ARTICLE

Effect of various milking equipment on milk ejection in high-yielding cows

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Improving modern dairy farming is based on the industry's development, which means transforming livestock farming into a competitive industry. The development of its technical and technological support is closely related to its functional ability to realize the genetic potential of biological objects of production with high-quality products, which is the defining criterion for the competitiveness of machinery and technology at the industry's present stage of development. The purpose of the research was to study milk production technology based on a comprehensive assessment and implementation of modern milking equipment, maximizing animals' genetic potential and industry efficiency. We proved that applying the 'DeLaval' milking parlor under the same feeding and keeping animals ensured the proper completeness of milking and increased cows' milk yield. During the first, third, and highest lactations, the milk yield was 226 kg ($P<0.05$), 266 kg ($P<0.05$), and 214 kg ($P<0.05$), respectively. After-milking when applying ADM-8A averaged 175 ml, and only 45 ml when applying the 'DeLaval' parlor. When using the 'DeLaval' milking equipment, the milk production intensity of cows was 1.43 kg/min, and, with ADM-8A, it was 1.24 kg/min, which is 0.19 kg/min ($P<0.001$), or 15.3% higher.

Keywords: milking; milk yield; lactation; productivity of cows; milk ejection

Introduction

Milk production at dairy complexes is the first stage in obtaining dairy products, so milk quality depends on how the production technology is organized (Habtamu et al., 2018). Also, cattle quality depends on the efficiency of breeding young animals - namely, the quality of colostrum for feeding (Palii et al., 2020e).

Thus, the effective extraction of milk, which affects milk yield, is one of the crucial points related to milking technique and milking (Overton et al., 2017; Paliy, 2016). The correct implementation of the technological process of milking plays a leading role in obtaining high-quality milk. The intensity of milk ejection is an animal's individual property; it affects the time spent on milking, milking's completeness, and, ultimately, production costs (Paliy, 2019). Thus, the intensity of milk ejection determines the cost of labor and time to obtain one quintal of milk. Therefore, this indicator's improvement provides a tremendous economic effect (Ivanyos et al., 2020).

It is necessary to select an equivalent milk ejection reflex to remove a significant portion of the produced milk from the animal's udder. The primary manifestation of the milk ejection reflex, or let down, is a change in the tonus of the smooth muscles of the ducts and cisterns, the reduction of the myoepithelium of the alveoli, and, as a result, the relaxation of the tendon sphincters (Mantysaari et al., 2019; Paliy et al., 2020b). The most critical reflex is its latency period, which starts from the moment of stimulation of the receptor to the appearance of a response, and as the conditioned reflex strengthens, the latent period decreases and reaches a more or less constant value (Madsen et al., 2008).

It is established that the milk reflex in cows is a complex process that occurs in two phases. The first phase of the reflex, associated with the udder receptors' irritation, has a short latency period. Pulses through the afferent nerves reach the spinal cord, where the nerve impulses switch to the efferent pathways, which, reaching the mammary gland, provide the secretion of cysteric milk due to the relaxation of the sphincter of the teat. The second phase of the milk ejection reflex is carried out through the neurohumoral mechanism. At the same time, impulses from receptors of teats on afferent fibers arrive at a hypothalamic nucleus. The afferent pathway approaches the neurohypophysis, where afferent impulses promote the release of the hormone

oxytocin, which reaches the alveoli with the blood, causing myoepithelial cells to contract (Palii et al., 2020c; Sitkowska et al., 2018).
The lactation reflex of every cow has its characteristics associated with the higher nervous activity, but usually, it has a minimum latency period in the first months of lactation and the maximum - in the last ones. Thus, along with the unconditional reflexes of milk production, there are also conditioned ones, depending on the circumstances that precede milking and accompany it. As a result, a persistent stereotype is created, the violation of which can significantly affect the effectiveness of milk ejection (Huber et al., 2016; Palii et al., 2020b). The milking rate is closely related to the amount of milk yield, milking duration, the level of vacuum pressure, pulsation rate, the ratio of suction and compression strokes, and other indicators. The intensity of the milking reflex, the completeness of milking, the quality of milk, the physiological state of the mammary glands, and the productivity of cows in general during lactation depend on the quality of performance of individual elements of the operation of milking and their interaction (Palii et al., 2020f; Shtepa et al., 2020).
Scientific and economic experiments show that the milking technique affects milk productivity, composition, and properties of milk. If cows were after-milked, their productivity increased by 2.5%, and the content of skim solids, fat, and protein in milk increased. Besides, the size of the fat globules also increased. There is a statement (Osipenko et al., 2018) that increasing the protein content in cows' milk is also possible. Compliance with the technological requirements for machine milking of cows is essential for improving the analytical techniques and methods of operators' work, contributing to the manufacture of a higher amount of products and increasing productivity by 10-13% (Palii et al., 2020d). As noted (Bradford et al., 2015; Dmytriv et al., 2018; Palii & Palii, 2019), the specialization and concentration of production, the introduction of advanced methods of keeping cows, the formation of highly productive lines is the essential factor in the effective use of machinery in animal husbandry.
The purpose of the research was to study milk production technology based on a comprehensive assessment and implementation of modern milking equipment, which allows to maximize the genetic potential of animals and increase the efficiency of the industry. We planned to study the impact of the milking equipment on the milk productivity of cows and to determine the intensity of milk ejection in cows when using milking plants ADM-8A and 'DeLaval'.

Materials and Methods

The 'DeLaval' system's operation is as follows: when the intensity of milk ejection is reduced to 200 ml/min at the beginning and end of milking, the milking machine works in a gentle mode (vacuum - 33 kPa, frequency - 48 pulses per minute). During the milking, the device works at the vacuum of 48 kPa with a frequency of 60 pulses per minute. Two groups of analog pairs were formed to study cows' milk productivity in the context of lactation. Each group included 97 cows, taking into account the linear affiliation, the cows being at the age of at least three lactations. Two groups of analog pairs were formed to study the milk ejection intensity with different milking equipment, following the guidelines (Ovsjannikov, 1976). These groups were formed considering the linear affiliation of cows, milk yield and fat content in milk during the previous lactation, age of calvings, and a month of lactation. The first group includes the animals that were milked using a milking machine ADM-8A, the second group - the milked animals using the 'DeLaval' milking parlor. All cows were on 2-3 months of lactation, the difference in calving time did not exceed 40 days.
The study was performed using the following tools: a stopwatch, a record sheet, and a pencil. During milking, the beginning and end of milking of each cow were clearly recorded. The intensity of milk ejection was determined by the level of single milking and the time spent on milking the cow. Data analysis was performed based on the results of milking two adjacent days. Processing of milk ejection dynamics records was performed according to the following indicators: total milking time of the cow; duration of machine and after-milking; the intensity of milk ejection in the first, second and third minutes of milking; the average intensity of milk ejection for the first 3 minutes of milking; the degree of completeness of milking for the first, second and third minutes of milking. The total milking time was calculated according to the formula:

$$T=t_1+t_2+t_3, \quad (1)$$

where t_1 - the duration of machine milking (from the moment of putting on the fourth milking teat cup to the reducing the intensity of milk ejection - less than 200 g/min); t_2 - the duration of idle milking (from the moment of intensity reduction to the beginning of machine after-milking); t_3 - the duration of machine after-milking (from the beginning of machine after-milking to the moment of removal of milking teat cups).
The total milk yield (q) in kg was determined according to the formula:

$$q = q_1 + q_2, \quad (2)$$

where q_1 - the amount of machine milk yield, kg; q_2 - the amount of milk machine gained by after-milking, kg.
The average intensity of milk ejection (Q) in kg/min was calculated according to the formula:

$$Q=\frac{\Sigma(q_1+q_2)}{\Sigma(t_1+t_2)}, \quad (3)$$

where t_1 - the duration of machine milking, min; t_2 - the duration of machine after-milking, min.
The maximum intensity of milk ejection was determined by analyzing the data obtained every 15 s of milking. It was recorded at what minute the maximum intensity of milk ejection was observed, which allowed for assessing the quality of the realization of the milk ejection reflex in cows at each experimental milking parlor. Manual after-milking was performed after turning off the milking machine; all teats were milked only once before the complete milking of each lobe, and the udder massage was not performed.
The results of studies of the process of milk let down in cows at different types of milking parlors made it possible to make a comparative assessment and substantiate the conclusion about the adequacy of animals' physiological needs. The results of

the research were processed by the method of variation statistics based on the calculation of the arithmetic mean (X), the deviation of the indicators from the arithmetic mean error (S_X), and the validity of the difference between the compared indicators (p).

Results and Discussion

The studies of the efficiency of using the 'DeLaval' milking parlor showed that this milking equipment increases cows' milk yield and increases milk fat content under the same conditions of feeding and keeping animals.
We studied cows' milk productivity at the initial stage when using milking equipment 'DeLaval' and ADM-8A in the first, second, and third lactations (Table 1).

Table 1. Productivity indicators and service period of the cows during their first lactation when applying various milking equipment

Indicator	ADM-8A	'DeLaval'
Number of cows, heads	97	97
Milk yield for 305 days of lactation, kg	3257±58	3483±64*
Number of active days	287.6±1.9	292.1±2.9
Fat content, %	3.90±0.02	4.08±0.02***
Fat content, kg	127.0±2.44	142.1±2.78***
Average daily milk yield of natural fat content, kg	11.3±0.19	11.7±0.25
Average daily milk yield of essential (3.4%) fat content, kg	13.0±0.24	14.3±0.32**
Service period, days	86.0±4.76	85.2±4.17

* P<0.05, **P<0.01, *** P<0.001

We revealed that the productivity of cows during the first lactation when milking with the 'DeLaval' parlor exceeds the productivity when milking with the ADM-8A installation: milk yield by 226 kg (P<0.05), or by 6.9%, and fat content by 0.18% (P<0.001) in absolute terms.
The average daily milk yield of natural fat when using imported equipment was 11.7 kg, that of essential fat was 14.3 kg, which is by 3.5% and 11.0% (P<0.01), respectively, higher than when using milking installation ADM-8A. There were no significant differences in the length of the service period in cows after the first lactation.
During the second lactation, the cows' productivity indicators and reproductive qualities also argue for the 'DeLaval' milking parlor (Table 2).

Table 2. Productivity indicators and reproductive qualities of the cows during their second lactation when using various milking equipment

Indicator	ADM-8A	'DeLaval'
Number of cows, heads	97	97
Milk yield for 305 days of lactation, kg	3961±77	4227±72*
Number of active days	286.4±2.48	291.0±2.98
Fat content, %	3.94±0.03	4.20±0.03***
Fat content, kg	156.1±3.14	177.5±3.47***
Average daily milk yield of natural fat content, kg	13.9±0.29	14.5±0.27
Average daily milk yield of primary (3.4%) fat content, kg	16.0±0.32	17.9±0.37***
Service period, days	79.3±4.81	76.9±2.35
Dry period, days	75.3±3.4	84.0±5.75

* P<0.05, *** P<0.001

We found that the use of the 'DeLaval' milking equipment allowed to increase the milk yield of the cows during the second lactation by 266 kg (P<0.05), or 6.7%, and fat content by 0.26% (P<0.001) in absolute terms. The average daily milk yield of natural fat content was 14.5 kg that with actual fat content was 17.9 kg, which is 4.3% and 11.9% (P<0.001) higher than when using the ADM-8A parlor.
During the third lactation, the cows milked with the imported milking equipment produced 4461 kg, or 214 kg (P<0.05) kg more than when using the domestic milking machine ADM-8A (Table 3).

Table 3. Productivity indicators and reproductive qualities of the cows during their third lactation when using various milking equipment

Indicator	ADM-8A	'DeLaval'
Number of cows, heads	97	97
Milk yield for 305 days of lactation, kg	4447±79	4661±68*
Number of active days	293.9±2.11	300.0±1.75*
Fat content, %	3.97±0.02	4.28±0.02***
Fat content, kg	176.5±4.03	199.5±3.07***
Average daily milk yield of natural fat content, kg	15.5±0.27	15.6±0.43
Average daily milk yield of essential (3.4%) fat content, kg	17.7±0.33	19.6±0.57**
Service period, days	86.7±5.33	106.5±6.78*
Dry period, days	70.1±3.18	79.2±2.67

* P<0.05, ** P<0.01, *** P<0.001

During the third lactation, the fat content in cows' milk was 3.97% and 4.28% when using milking equipment ADM-8A and 'DeLaval', respectively. The introduction of imported equipment contributed to an increase in the fat content of the milk of cows during the third lactation by 0.31% (P<0.001) in absolute terms. When using various milking equipment, the average daily milk yield of natural fat of cows on the third lactation does not differ significantly, and that of actual fat content, when milked with the 'DeLaval', is higher 1.9 kg (P<0.01). The number of active days when using imported equipment was higher by 6.1 days (P<0.05), which indicates that, under identical feeding and keeping conditions, the imported equipment contributes to a complete milk extraction from the udder of a cow. The better the cow is milked, the more milk fat will be obtained from it, as the last portions of milk contain it in more significant quantities.

At the next stage of the research, the cows' milk yield for the period from June 2019 to May 2020, i.e. during a year of operation of the milking parlor (Fig. 1), was analyzed.

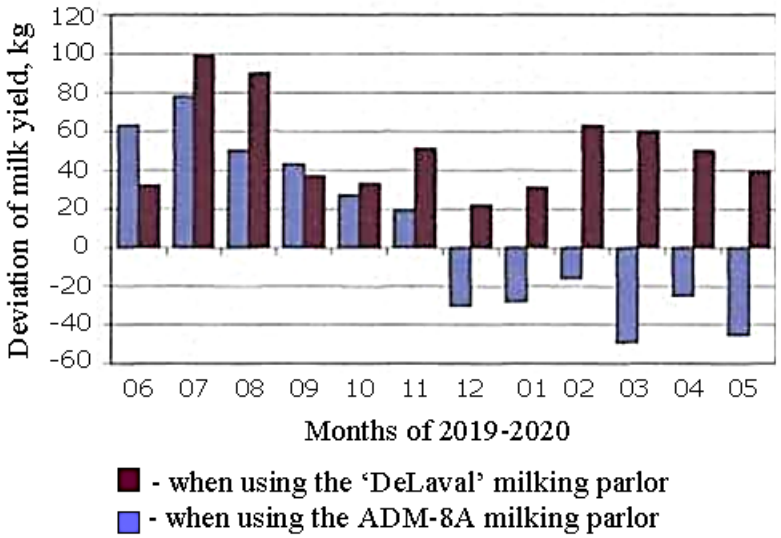

Figure 1. Deviation of milk yield of the cows from June 2019 to May 2020 compared with last the previous year's level.

The increase in milk yields during milking with the 'DeLaval' was lower than that when milking with the domestic equipment in June 2019, which was associated with stress and adaptation of the cows to new milking conditions. The increase in milk yield per cow when using the new milking equipment was much higher in those months. However, when using the ADM-8A installation from December 2019, there is a decrease in milk yield compared to the previous year.

The next step of the research was to study the intensity of milk ejection in cows using the ADM-8A and 'DeLaval' milking parlors (Table 4).

Table 4. The intensity of milk ejection in cows when applying various milking equipment

Indicator	ADM-8A	'DeLaval'
Daily milk yield, kg	13.9±0.5	13.2±0.6
Duration of milking, min	11:35±00:11	09:32±00:08***
The intensity of milk ejection, kg/min	1.24±0.06	1.43±0.07*

* P<0.05, *** P<0.001

We registered that when using the 'DeLaval' milking equipment, the intensity of milk ejection of cows was 1.43 kg/min, and with ADM-8A it was 1.24 kg/min, which is 0.19 kg/min (P<0.05), or 15.3% higher, which indicates the need to adjust the regulations of keeping cows and saves milking machine operators' labor costs. The data on the completeness of milking cows also testify in favor of the modern milking parlor. The cows were after-milked manually, and we measured the amount of milk with a cylinder. Thus, after-milking, the amount of milk obtained by milking with the ADM-8A unit averaged 175 ml, and when milking with the 'DeLaval' parlor, it was only 45 ml. The amount of after-milking, even in the volume of 100 g, reduces secretion and the level of milk yield. Manual after-milking can provide complete milking, but it is very time and labor-consuming. Besides, residual milk has the highest fat content indicator. Complete extraction of milk can increase the overall productivity of the herd. Therefore, the use of milking machines that stimulate milk production has a good effect.

It is essential to empty the udder as wholly as possible, as the last portions of milk have the highest fat and protein content. Therefore, the better the cow is milked, the more milk fat and protein will be obtained from it (Palii et al., 2019; Stoop et al., 2009). Mishra et al. (2020) confirm the importance of stimulating milk ejection. Adherence to all milking rules allows increasing the intensity of milk ejection by 0.14-0.36 l/min. According to the data (Dmytriv et al., 2018), up to 5% of milk yield is lost using worn-out milking equipment. According to (Odorcic et al., 2019; Paliy et al., 2018; Zbinden et al., 2017), the operations performed during machine milking are subdued to the physiology of milk production and do not depend on the type and design of the milking machine or the method of organization milking. The order of these operations in each milking process should be the same, both in sequence and duration.

During machine milking, there is a significant potential to increase the rate of milk excretion from the udder of cows. The milking machine should stimulate an unconditional reflex in cows. The lactation reflex activity depends on the strength and nature of the influence of the milking machine on the nerve endings of the udder teats. An essential role in several factors that can significantly affect milk production belongs to the teats' force of compression. Therefore, the most significant influence on the intensity of milk ejection is exerted by the stiffness and elasticity of teat rubber, which, in turn, directly depend on its quality, storage conditions, duration of operation, as well as correct installation and adjustment in the milking cup (Paliy et al., 2020a).

It should be borne in mind that the lactation reflex may be inhibited or not manifested because of sharp noises and brutal treatment of cows. In such cases, the endocrine glands secrete the hormone adrenaline, which sharply narrows the milk ducts and delays the secretion and movement of oxytocin, as a result of which the cow 'does not entirely let down' milk (Gross & Bruckmaier, 2019; Palii et al., 2020g).

The conditioned reflex to milk let down is developed and maintained in cows under the influence of a specific daily routine that is not changed on the farm, which creates a so-called dynamic stereotype, the violation of which inhibits the lactation reflex and weakens the secretory activity of the breast. The rate of milk ejection depends on cows' characteristics of higher nervous activity: it is usually highest in animals with a balanced mobile type of nervous system (McArt et al., 2015; Palii et al., 2020a). Thus, the research confirms that a milking machine with a device for controlling the milking process ('DeLaval') has a stimulating effect on milk production and provides a higher intensity of milk ejection and completeness milking. As a result of the above, we can say that milk yield is an essential indicator which, on the one hand, determines the potential of animals in terms of their use in intensive technologies, and, on the other hand, testifies to the quality of conditions that allow manifesting this potential.

In the modern understanding of milk production technologies, the rate of milk ejection is essential. First of all, the milk ejection rate is the most vital sign of cows' suitability for machine milking, which depends on several factors: reflex perception of machine milking, hormonal regulation of milk ejection, udder morphology, type of highest nervous activity, and others. The rate of milk ejection indicates not so much the time of milking animals, as the prerequisites for a positive reflex perception of milking, easy filling udder with milk before milking, as well as readiness for repeated milking with a high shutdown threshold of milking machine (Ivanyos et al., 2020; Mantysaari et al. 2019; Palii et al., 2020b).

In modern milking equipment, many parameters are set depending on the rate of milk flow. The milk ejection rate determines such essential parameters as a shutdown threshold of the milking machine, the threshold of the machine stimulation, the on and off threshold for the change in the duration of cycles (Palii & Palii, 2019).

In the conditions of farms and dairy complexes of industrial-type high-productive, the cows with milk yields of 8-10 thousand and more kilograms of milk per lactation start to be widely used. As a result, the requirements for milking equipment are increasing. Therefore, to maintain milking equipment in good condition with synchronous interaction, 'machine-animal-human' is modern dairy enterprises' task. Thus, milking animals' completeness for a short period, maintaining the cow's health, and obtaining high-quality milk are the main criteria for modern milking equipment's effectiveness. A progressive trend in the development of modern milking equipment is the creation and application of various composite materials and technologies and the widespread use of elements of 'intelligent' equipment. Milk is of the highest grade can be obtained on the assumption of the technical re-equipment of farms and complexes with modern milking parlors and the equipment for primary processing of milk, which meets all the requirements. In connection with the above, there is a need to develop and study an algorithm for selecting milk production parameters depending on animals' individual and phenotypic characteristics for specific production conditions.

Conclusion

For the first, third, and highest lactations, when using the 'DeLaval' milking parlor, the advantage in milk yields (compared to the milking unit ADM-8A) was 226 kg (P<0.05), 266 kg (P<0.05), and 214 kg (P<0.05), respectively. The volume of after-milking in cows when milking with ADM-8A averaged 175 ml, and only 45 ml when applying the 'DeLaval' parlor. When using ADM-8A, the milk yield of cows was 1.24 kg/min, and with the 'DeLaval' milking parlor, it was 1.43 kg/min, which is 0.19 kg/min (P<0.001), or 15.3% higher.

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