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DYNAMICS OF DAIRY COW MILK PRODUCTIVITY AND FREQUENCY OF VISITS TO THE MILKING ROBOT UNDER A VOLUNTARY MILKING SYSTEM

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ABSTRACT: The study analyzed the frequency of voluntary visits to an automated milking system (AMS) by Holstein cows, along with milk yield indicators, functional characteristics of the udder, and the duration of intervals between milkings. The research was conducted at a farm in the Kyiv region using a loose-housing system and robotic milking. Trends in average daily milk yield and the frequency of visits to the milking robot were analyzed using data from the VMS-2012 automated control system, while milk yield was recorded using "Fullflow" electronic meters. Milk flow rate was determined based on the amount of milk obtained from individual udder quarters and the duration of milking. To evaluate the relationship between productivity and milking frequency, cows were categorized into five groups according to lactation milk yield (5000–6000; 6000–7000; 7000–8000; 8000–9000; and 9000–10000 kg) and according to lactation number (I, II, III, IV or higher). Animals belonging to the Chifa, Starbuck, and Montfrecht lines were evaluated separately, taking into account udder conformation, milk flow rate, and the proportion of milk obtained from individual udder quarters. It was found that cows with a lactation yield of 9000–10000 kg visited the milking robot more frequently—2.8 times per day—compared with animals yielding 6000–8000 kg, which visited it 2.6 times per day. As lactation number increased, the frequency of visits decreased, reaching 2.5 visits per day in cows in their fourth and subsequent lactations. The highest 305-day milk yield was recorded in cows in their third lactation, which visited the robot 2.6 times per day. First-lactation cows, despite having the highest visit frequency of 2.7 times per day, produced 9551 kg of milk during the 305-day lactation. Milk flow rates from individual udder quarters were similar, with slightly higher values observed in the rear quarters.

Keywords: Average daily milk yield, Cows, Lactation, Mammary gland, Milking robots, Udder.

INTRODUCTION

Modern innovative technologies in dairy farming in Ukraine are being implemented very slowly, despite their existing advantages and the new prospects they offer for this industry. The emergence of robotic systems, which are successfully used in dairy farming, has contributed to a technical and technological breakthrough (Heema et al., 2022; Sangode, 2025).

The use of milking robots has changed the approach to milking because the focus is now on the animal and its physiological and ethological needs (Brouček and Tongeľ, 2015; Legkodukh and Lutsenko, 2018). The main task of robotic milking is to increase milk yield by creating conditions that are as close as possible to natural ones. The use of this system contributes to the emergence of a practically new technology based on animal self-service that allows cows to freely choose the time and frequency of visits to the milking robot (Tousova, 2014; Simoes Filho et al., 2020).

When using the "voluntary" milking system, a stable milking routine is established by training cows to visit the robot independently. This allows each cow to decide when cow needs to be milked and when and for how long to rest (Kammann et. al., 2024). Experts have questions regarding this problem, but the main one is to determine the optimal technological parameters for the development of the mammary gland and the frequency of cows' visits to the milking robot without compromising their health, since untimely milking can lead to disruption of the milk secretion process, and ultimately to a decrease in milk yield (Beggs et al, 2015; Simoes Filho et al, 2020; Chikurtev et al., 2024). In addition, many studies show that the frequency of milking affects the quantity and quality of milk (Mačuhová et al., 2020;

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Meijering et al., 2023). It was found that milking three times increased milk yield by 1.72 kg compared with milking twice (Sánchez-Duarte et al., 2020). Robotic milking ensures complete milking of cows according to their physiological state and the accumulation of milk in the udder, which also help prevents the occurrence of mastitis (Legkodukh and Lutsenko, 2018; Chikurtev et al., 2024).

The pattern of cows' visits to the milking robot, depending on milk yield and age at lactation, remains a relevant topic for study. Since voluntary milking systems are not widespread in Ukraine, in our opinion, the principles of operation of automatic milking systems are of scientific interest and require in-depth research. Based on the above, the goal of our work was to investigate the dynamics of milk yield and the frequency of cows' visits to the milking robot under a voluntary milking system.

MATERIALS AND METHODS

Animals

The study was conducted at the Terezine cattle farm, Bila Tserkva district, Kyiv region, Ukraine. The farm breeds Holstein cattle and is the first farm in Ukraine to install a robotic milking system. The farm uses a loose housing system for cows.

Feeding

Feeding cattle is an important aspect of production and management; the farm selects only high-quality feed and provides the animals with feed produced on the farm. Feed samples are sent to the laboratory, where their quality is determined. To obtain high-quality products from cows, a nutritious and balanced diet containing several types of feed is essential. The feed ration consisted of 9 kg of compound feed, 28 kg of silage, 8 kg of haylage, 1 kg of straw, and 0.3 kg of hay.

Experimental design

The dynamics of average daily milk yields and the frequency of visits to the milking robot by Holstein cows of different lactations and milk yield levels were studied using the automatic milking control system installed in the VMS-2012 unit. The milk flow rate from the udder quarters of cows was determined by dividing the amount of milk obtained in the morning by the duration of milking, expressed in kg/min. Milk yield indicators for each animal were assessed using an automated information collection system based on electronic "Fullflow" flow meters.

To assess the relationship between milk production and the frequency of visits to the milking robot, the cows were divided into five groups according to total milk yield per lactation: 5,000–6,000 kg (n = 64), 6,000–7,000 kg (n = 68), 7,000–8,000 kg (n = 84), 8,000–9,000 kg (n = 76), and 9,000–10,000 kg (n = 61). Within each group, the average number of visits to the milking robot per day and the average daily milk yield were determined.

To identify lactation-related differences in the use of the voluntary milking system, the cows were grouped according to lactation number: first lactation (n = 145), second lactation (n = 92), third lactation (n = 71), and fourth and subsequent lactations (n = 44). For each group, the average number of visits to the milking robot per day, average daily milk yield, and total milk yield per lactation were determined.

To assess the effects of genetic line and udder morphology on milk production, cows belonging to the Chifa, Starbuck, and Montfrech lines were analyzed. For each line, udder shape (cup-shaped, bath-shaped, and round), milk yield during the first, second, and third lactations, and milk flow rate were evaluated. In addition, the productivity of cows from different lines was compared according to lactation number and the two most common udder shapes, cup-shaped and bath-shaped. Functional characteristics of the udder under voluntary robotic milking conditions were evaluated in 120 Holstein cows. The analysis was performed according to lactation number, taking into account the proportion of milk obtained from each udder quarter.

Statistics

Statistical analysis of the research results was carried out using Microsoft Excel 2021 and Statistica 10.0 software. The arithmetic mean (M) and standard error of the mean (m) were determined. The significance of differences between the indicators was assessed using Student's *t*-test. A difference was considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

One of the main criteria for the suitability of cows for robotic milking is udder shape. The most suitable are cup-shaped, tub-shaped, while round-shaped udders are less desirable. The assessment of the udders of cows on the farm was carried out across three lines: Chief, Starbuck and Montfrecht (Table 1). Analysing udder shape, it was found that the largest number of animals on the farm had cup-shaped udders. The highest percentage of animals with this udder shape belonged to the Chief line (76.2%), while in cows of the Starbuck and Montfrecht lines, this figure was 6.7% and 18.8% lower, respectively. Tub-shaped udders prevailed in cows belonging to the Montfrecht line (36.2%). It should also be noted

that the smallest proportion of animals in all three studied groups had round-shaped udders: 3.2% in cows of the Chief line, 5.5% in Starbuck, and 6.4% in Montfrecht.

Analysis of milk yield showed that the highest milk yield during the first and third lactations were recorded in animals of the Chief line, at 8308.9 kg and 10112.69 kg, respectively. These yields exceeded those of cows of the Starbuck line by 428.6 kg and 70.19 kg, and those of the Montfrecht by 902.5 kg ($P < 0.001$) and 454.09 kg, respectively. Milk yield during the second lactation was higher in cows of the Starbuck line reaching 9379.2 kg. The difference between the groups was 44 kg compared with the Chief line and 573.08 kg compared with the Montfrecht line. The average milk flow rate was highest in animals of the Chief line (2.53 kg/min); however, the difference compared with the other two groups was not statistically significant. The next task was to analyze the influence of udder shape on milk production in cows. The results of the study are shown in Figure 1.

Table 1 - Udder and teat shape depend on lineage

Lines	Udder shape			Milk yield during lactation			Milk flow rate, kg/min
	cup-shaped %	bath-shaped %	rounded %	I	II	III	
Chief	76.2	20.6	3.2	8308.9±164.4	9334.3±333.4	10112.69±225.4	2.53±0.04
Starbuck	69.5	25	5.5	7880.3±186.3	9379.2±279.8	10042.5±223.2	2.48±1.11
Montfrecht	57.4	36.2	6.4	7406.4±186.3***	8806.12±591.8	9658.6±285.3	2.45±0.10

***: $P < 0.001$

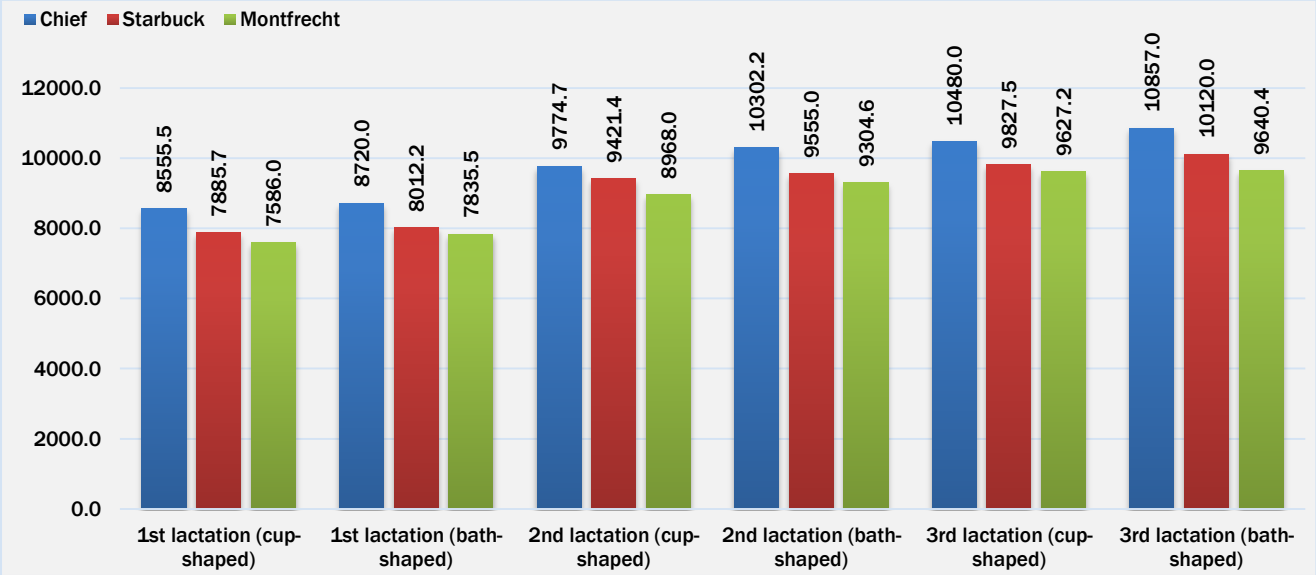

Figure 1 - Milk yield per lactation depending on udder shape and linearity.

The study showed that in animals with tub- shaped udders, milk yield was slightly higher than in animals with cup-shaped udders. The differences between the indicators within the Chief line were as follows: 165 kg in the first lactation - 527.5 kg in the second lactation, and 177.8 kg in the third lactation. In animals belonging to the Starbuck and Montfrecht lines, there was also a tendency toward higher yields in cows with tub- shaped udders. In the first lactation, the differences were 126.5 kg and 249.5 kg; in the second lactation 133.6 kg and 366.6 kg; and in the third lactation, 292.5 kg and 13.2 kg, respectively. Analysis of the milk yield of cows from the studied lines according to udder shape showed that animals belonging to the Chief line had higher milk yields throughout lactation, regardless of udder shape. Offspring of the Chief line with cup- shaped udders in the first lactation produced 669.8 kg and 969.5 kg more milk than cows of the Starbuck and Montfrecht lines, respectively. Among animals with tub-shaped udders, the corresponding differences were 707.8 kg and 884.5 kg, respectively. In the second lactation, the differences for cup-shaped udders were 353.3 kg and 806.7 kg, while for tub-shaped udders, they were 652.5 kg and 1175.6 kg, respectively. In the third lactation, the differences for cup-shaped udders were 625.5 kg and 852.8 kg, while for tub-shaped udders, they were 737 kg and 1216.6 kg, respectively. In the next stage of the research, milk yields per lactation were analyzed, and the results are presented in Table 2. It should be noted that there was a certain pattern of increase in this indicator with increasing milk yield, both on a daily basis under per lactation. As milk yield increased from 5000 to 7000 kg per lactation, average daily milk yield increased from 14.9 to 17.7 kg ($P < 0.001$). At a yield of 7000–8000 kg of milk per lactation, the frequency of visits decreased, similarly to the pattern observed in cows producing 5000–7000 kg of milk per lactation.

From the results obtained, it can be assumed that cows with a milk yield of 7000–8000 kg per lactation have the most optimal mammary gland size and development. Animals with lower milk yields may have an underdeveloped mammary gland, which requires more frequent emptying to optimize its functioning. A similar response is observed with milk yields exceeding 8000 kg per lactation (average daily milk yield above 23 kg; $P < 0.001$), which is also quite natural.

Analysis of changes in the frequency of visits to the milking robot by cows of different lactations (Table 3) indicates a relationship between the age of the animals and, consequently, the size and development of the mammary gland and the frequency of its emptying. Under the voluntary milking system, cows in their first and second lactations, with average lactation milk yields of 9551.0 and 10156.3 kg, respectively, visited the milking robot an average of 2.7 times per day. Mature and older cows in the third, fourth, and subsequent lactations visited the milking robot slightly less frequently - 2.6 and 2.5 times per day, respectively—while maintaining practically the same level of milk production (10224.4 and 10002.1 kg, respectively).

Table 2 - Number of visits to the milking robot per day by cows of different yield level breeds

Milk yield	N	Frequency of visits, times	Average daily milk yield, kg
		M ± m	M ± m
5000–6000	64	2.6±0.05	14.9±0.13
6000–7000	68	2.6±0.04	17.7±0.07***
7000–8000	84	2.5±0.01	20.5±0.10***
8000–9000	76	2.7±0.04	23.3±0.09***
9000 -10000	61	2.8±0.07	26.1±0.10***

***: $P < 0.001$ compared with the 5000–6000 kg milk-yield group

Table 3 - Number of visits to the milking robot per day by cows of different ages in lactation and their yield

Age of cows in lactation	N	Frequency of visits, times	Daily milk yield, kg	Lactation milk yield, kg
		M ± m	M ± m	M ± m
I	145	2.7±0.02	26.2±0.43	9551±158
II	92	2.7±0.01	27.8±0.93	10156.3±339.6***
III	71	2.6±0.0	28±0.88	10224.4±322.8***
IV and older	44	2.5±0.02	27.3±1.09	10002.1 ±406.0***

***: $P < 0.001$ compared with the first-lactation cows

In the studied cows, average daily milk yield increased from the first to the third lactation. Compared with first-lactation cows, average daily milk yield was 1.6 kg higher in second-lactation cows and 1.8 kg higher in third-lactation cows. In cows in their fourth and subsequent lactations, average daily milk yield exceeded that of first-lactation cows by only 1.1 kg. The highest average daily milk yield was recorded in third-lactation cows (28.0 kg) after which it slightly decreased to 27.3 kg in cows in their fourth and subsequent lactations.

It was also important to investigate how average daily milk yield and the frequency of visits to the milking robot by cows of different lactation ages changed during lactation. The dynamics of changes in milk yield throughout lactation can be assessed using the indicators of the lactation curve. Thus, in primiparous cows (Figure 1), milk yield increased fairly evenly, reaching a maximum in the fifth month of lactation, when it amounted to 30.3 kg. The frequency of visits to the milking robot was highest in both the fifth and sixth months of lactation, amounting to 3.3 visits per day.

Analysing changes in average daily milk yields in cows in their second lactation (Figure 2), the researchers see that the curve reaches a maximum in the third month of lactation (32.2 kg), while the peak frequency of visits to the milking robot occurs in the fifth month, at 3.2 visits per day. Therefore, the level of average daily milk yields in individual months of lactation does not reflect the frequency of visits to the milking robot.

Analysing the nature of the lactation curve in cows in their third lactation (Figures 3-5), the researchers see that milk yields increase steadily until the third month of lactation (34 kg). At the same time, the frequency of visits to the milking robot increases in parallel with milk yields, reaching 3.3 visits per day, followed by a gradual decrease in both milk yields and the frequency of visits. This indicates that in cows in their third lactation, which have sufficiently high milk yields, the lactation curve is more stable, and the frequency of visits reflects the level of daily milk yields.

In cows in their fourth lactation (Figure 4), there is a rapid increase in milk yields until the second or third month of lactation, followed by a significant decrease. The frequency of visits to the milking robot is initially somewhat lower than the increase in milk yield and then significantly exceeds it. By the end of lactation, it does not correspond to the milk yield values. In our opinion, in this case, a reflex component may be involved, namely, the receipt of a portion of compound feed during milking. Therefore, such cows can be milked twice a day starting from the fifth month of lactation.

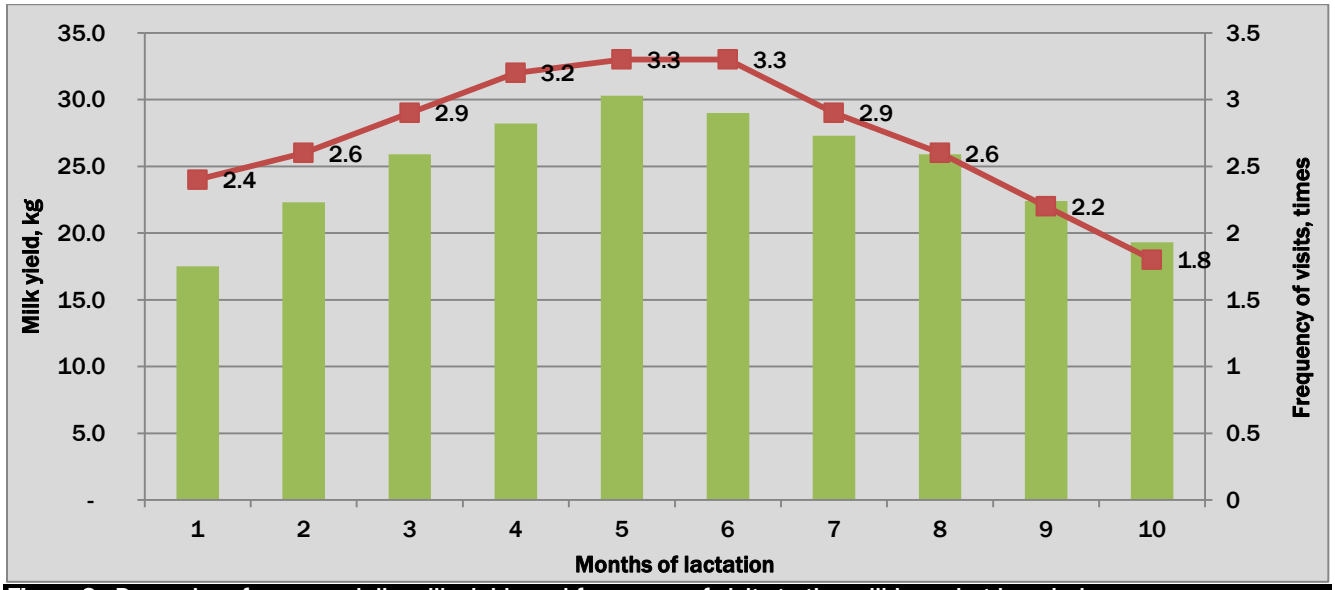

Figure 2 - Dynamics of average daily milk yields and frequency of visits to the milking robot by primiparous cows.

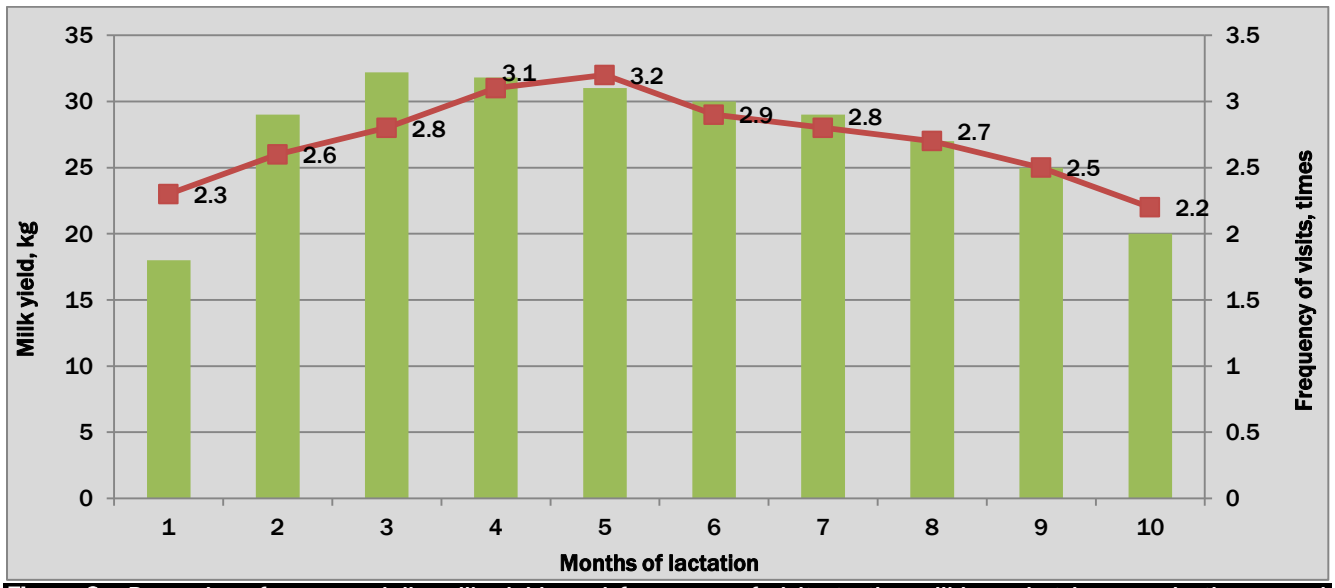

Figure 3 - Dynamics of average daily milk yields and frequency of visits to the milking robot by cows in the second lactation.

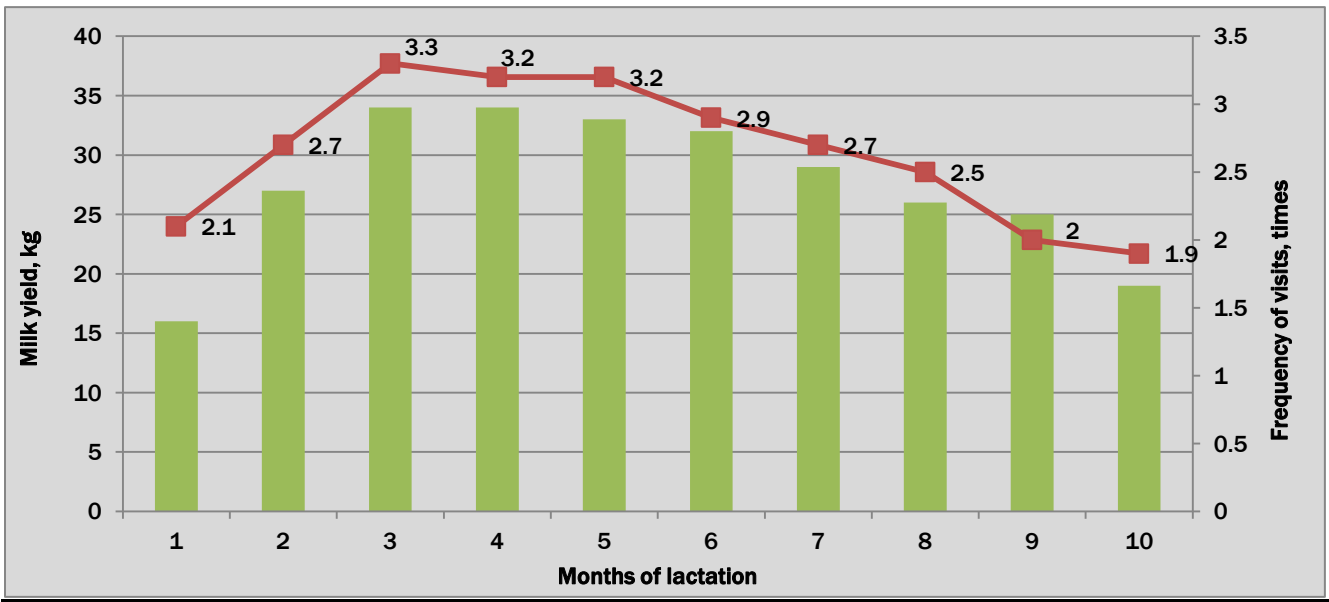

Figure 4 - Dynamics of average daily milk yields and frequency of visits to the milking robot by cows in the third lactation.

For quite a long time, scientists have been interested in studying the development of individual parts of the udder in cows of different breeds. However, even today, due to the limitations of existing devices and methods, this issue has not been sufficiently studied, and the results obtained are not readily comparable. Therefore, we conducted a study to determine the capacity of individual parts of the udder in Holstein cows. The results of the study are presented in Table 4.

When assessing the capacity of individual udder quarters in cows, it was found that, regardless of age and lactation number, the smallest amount of milk was concentrated in the left anterior quarters. Thus, in primiparous cows, the capacity of the right anterior quarters, compared with the left anterior quarters, was higher by 3.4%, that of the left posterior quarters (LP) by 11.7%, and that of the right posterior quarters (RP) by 10.4%. In cows in their second lactation, the differences were 5.0% for the right anterior quarters, 14.9% for the left posterior quarters, and 17.7% for the right posterior quarters. In cows in their third lactation, the corresponding differences were 3.0%, 12.4%, and 13.4%, respectively, while in cows in their fourth and subsequent lactations, they were 4.1%, 10.2%, and 11.3%, respectively. Thus, the largest difference in the capacity of individual udder quarters was observed in cows in their second lactation.

Cows in their third, fourth, and subsequent lactations had indicators close to those of primiparous cows. In this regard, it can be argued that, even under conditions of voluntary milking, a significant difference in the capacity of individual parts of the udder does not allow for increasing the yield of the milking robot.

Evaluating the milk production intensity index in Holstein cows under conditions of "voluntary" milking, it was established (Table 5) that there was no statistically significant difference in milk yields between cows of different lactation numbers (12.5–13.5 kg). Cows in all lactations were milked, on average, within the optimal period of oxytocin activity (up to 6 min). At the same time, cows in their third lactation were milked the fastest, while primiparous cows required the longest milking time. Regarding primiparous cows, it can be assumed that they were still poorly adapted to robotic milking, since the assessment was carried out in the second month of lactation, which may have affected the duration of milking.

Regarding milk flow rate, the highest value was recorded in cows in the second lactation. This value was higher than that of primiparous cows by 0.3 kg/min, that of cows in their third lactation by 0.1 kg/min, and that of cows in their fourth and subsequent lactations by 0.2 kg/min. As observed by other researchers, there was a positive correlation between milk flow rate and single milk yield, and a negative correlation between milk flow rate and milking duration. At the same time, the milk flow rate in Holstein cows under conditions of "voluntary" milking significantly exceeded the minimum requirement of 1.3 kg/min for this indicator, indicating the possibility of further improvement.

Analysing changes in the time intervals between milking in cows of different lactation numbers under conditions of voluntary milking (Table 6), it can be noted that the longest interval was observed at night, that is, between evening and morning milking.

Thus, in primiparous cows, its duration was 45.8% of the daily period, in second-lactation cows, 41.6%; and in third- and fourth-lactation cows, only 37.5%. Therefore, even under conditions of voluntary milking, the duration of the intervals between milking's tends to become more equal with increasing lactation number. However, an interval of 11 hours or more between milking's in primiparous cows indicates the possibility of milking them twice a day, which would not negatively affect milk yield or the processes of milk formation. The duration of the interval between morning and afternoon milking in cows of all lactations was almost the same, accounting for 29.2–33.3% of the daily period. Regarding the duration of the interval between afternoon and evening milking, some leveling was observed with increasing lactation number. Thus, in cows in their first and second lactations, the interval accounted for only 25% of the daily period, whereas in cows in their third lactation, it increased to 29.2%, and in cows in their fourth and subsequent lactations, to 33.3%.

Evaluating the pattern of visits to the milking robot by cows in the technological group (Figure 5), the researchers observed two major peaks: from 6 to 10 a.m. and from 6 to 10 p.m. A slight peak is also observed from 1 to 2 p.m. The lowest frequency of visits to the milking robot, as in the control group, was observed from 1 to 6 a.m. From 6 a.m. to 7 p.m., the milking robot was visited hourly by 3.5–5.5% of the cows in the technological group. The studies also showed that during the day, each cow, depending on its lactation number, visited the milking robot between one and three times.

Table 4 - Capacity of individual udder segments in Holstein cows under "voluntary" milking, (% of total udder milk yield) (n = 120)

Lactation	Udder parts			
	Left front	Right front	Left rear	Right rear
I	18.7	15.6	17.8	18.6
II	22.1	20.6	20.8	22.7
III	30.1	30.5	30.2	28.8
IV and older	29.1	33.3	31.2	29.9

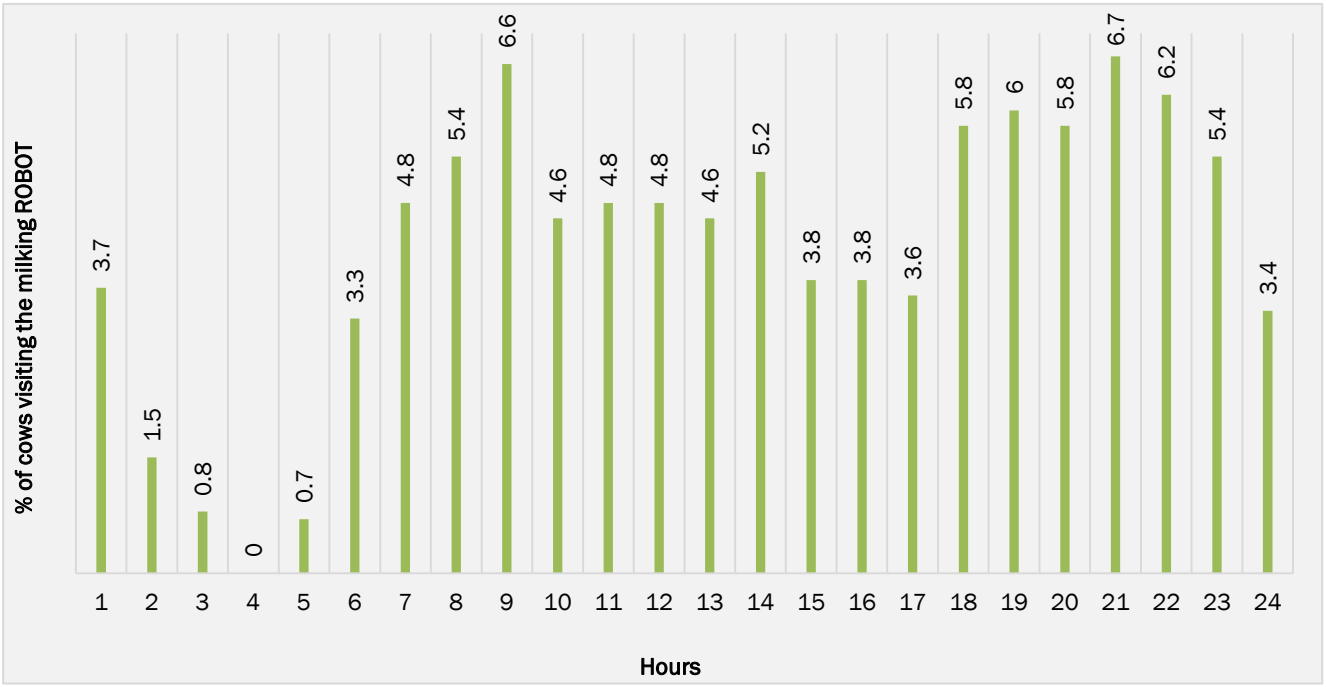

Figure 5 - Frequency of visits to the milking robot by cows

Table 5 - Milk production rates in "voluntary" milking cows

Lactation	One-time milk yield for morning milking, kg	Milking duration, min	Milk output intensity, kg/min
I	12.5±0.85	5.3±0.02	2.4±0.2
II	13.5±0.92	5.1±0.02	2.7±0.5
III	13.2±0.89	5.0±0.03	2.6±0.4
IV and older	12.9±0.9	5.1±0.02	2.5±0.4

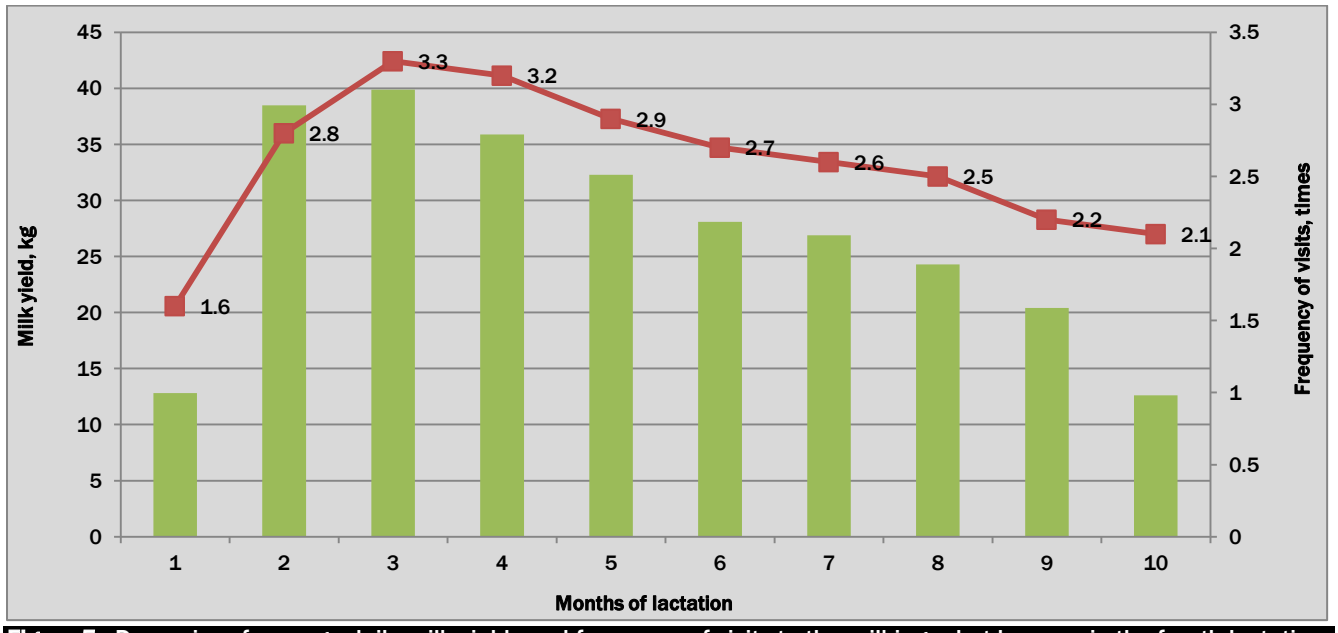

Figure 5 - Dynamics of average daily milk yields and frequency of visits to the milking robot by cows in the fourth lactation

Table 6 - Duration of time intervals between milkings during the day

Lactation	Time interval between milkings, hours (M±m)		
	Evening morning	Morning lunch	Lunch evening
I	11±0.22	7±0.21	6±0.21
II	10±0.15	8±0.22	6±0.23
III	9±0.10***	8±0.11	7±0.13
IV and older	9.1±0.13**	7.1±0.18	8±0.12

***: P < 0.001; **: P < 0.01.

Milk yield depends significantly on the size, morphological structure and shape of the udder (Klymkovetskyi and Nosevych, 2020). Analysis of animals belonging to three different lines showed that cup-shaped udders predominated in animals of each line. A significant proportion of the animals also had tub-shaped udders, while a small proportion had round-shaped udders. Analysis of milk yield depending on udder shape showed that, regardless of genetic line, milk yield was higher in cows with tub-shaped udders. This is also confirmed by the research results of Vedmedenko et al. (2019). According to his data, cows with cup-shaped udders produced 124.8 kg less milk during the first lactation, 129.7 kg less during the second, and 254.2 kg less during the third.

As a result of the conducted research, it was found that in cows in their first to third lactations, a general trend was observed: as average daily milk yield increased the frequency of visits to the milking robot also increased. In cows in their fourth and subsequent lactations, a significant decrease was observed. In our opinion, this indicates that at this age, udder size reaches its maximum, ensuring optimal functioning of the mammary gland without negatively affecting the pattern of milk formation.

There is no consensus in the literature on this issue. Some authors (Borshch and Ruban, 2015) believe that the higher a cow's daily milk yield, the more frequently it is milked. Thus, cows producing 25.2 kg of milk per day visited the milking robot an average of twice, whereas cows producing 29.05–29.39 kg visited it three and sometimes four times.

Conflicting data have also been obtained regarding the frequency of milking cows. Studies by De Koning (2010) and Habibi et al. (2021) found that when the frequency of milking was reduced from four to two times per day, while maintaining the same housing and feeding conditions, milk yield decreased by 4.4–13.7%. The magnitude of these changes largely depended on the animals' milk yield. We conducted a study to assess the relationship between the frequency of visits to the milking robot per day and milk yield. The results showed that milking frequency had a certain effect on cow milk yield. The highest milk yield over 305 days of lactation (10,224.4 kg of milk) was achieved by cows in their third lactation, which were milked 2.6 times per day. Their yield exceeded that of cows in their first and second lactations by 0.6% and 6.6%, respectively. The lowest yield (9,551 kg of milk) was achieved by primiparous cows, which visited the milking robot 2.7 times per day.

The question of the frequency of milking cows of different lactation numbers and milk yield levels is constantly being raised and addressed by many researchers (Jensen et al., 2018; Sanchez-Duarte et al., 2020). They found that intensive milk production occurs when the udder is sufficiently filled with milk. At the same time, studies by Kosior et al. (2009) and Mangalis et al. (2021) established that reducing the frequency of milking after calving does not reduce milk yield. Folley (1961) also stated in his work that cows produce milk more efficiently at the beginning of lactation than at the end. As milk secretion decreases, the intensity of the milk ejection reflex also decreases, and the relative amount of residual milk increases. From a physiological point of view, more frequent milking (three times per day) allows more milk to be obtained from cows than twice-daily milking. However, the difference in milk yield depends on the age of the animal, its milk yield, and the stage of lactation. In addition, switching to a twice-daily milking regime also has certain advantages (Hogeveen et al., 2001; Borshch, 2016). Nevertheless, all authors agree that with increasing age, the milk yield of animals increases, then stabilizes at a certain maximum, and subsequently decreases until the end of their productive lives (Kostenko, 2005; Solano et al., 2022; Kepkalo et al., 2024).

The results of the present study showed that the milk flow rate from the udder quarters was almost the same but slightly higher in the hind quarters. With increasing age, certain changes were observed in the capacity of individual udder quarters. Regarding milk flow rate in primiparous cows, the lowest value was recorded in the left quarters, where it was 3.4% lower than in the right quarters. Depending on lactation number, the difference in milk yield between the left posterior (LP) and right posterior (RP) quarters was 4.2%. From the first to the fourth lactation, milk yields in the LP quarters remained unchanged, while those in the RP quarters increased slightly. In cows, regardless of lactation number, only 15.8–18.7% of the daily milk yield accumulated in the LP quarters.

The results of the present research confirm the findings of Kostenko (2005), who reported that, regardless of breed, breed combination, lactation number, and milking frequency, the left anterior quarter of the udder is the least developed in cows. The duration of milking in this quarter is shorter by 1.4–96.6%, milking frequency is lower by 4.6–95.6%, and the milking intensity is lower by 2.6–68.7% than in the other quarters of the udder. The difference between the optimal value (25%) and the established milking index in the udder quarters of cows of different breeds and breed combinations

averages 0.2–11.9%. Therefore, the functional development of individual udder quarters is uneven, even under a "voluntary" milking system.

CONCLUSION

According to the results of the study, it was found that, regardless of lactation number, the frequency of visits to the milking robot increases with an increase in average daily milk yield. The maximum udder capacity of Holstein cows is reached by the fourth and subsequent lactations, as evidenced by a decrease in the frequency of visits to the milking robot at the same daily milk yield. It was also found that cows visit the milking robot due to physiological needs. In addition, the intervals between milkings are regulated by the functional state of the mammary gland and become more uniform with increasing lactation number.

DECLARATIONS

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Ethical regulation

The study followed the rules for the treatment of animals in accordance with the European Convention for the Protection of Vertebrate Animals used for Research and Other Scientific Purposes (1986). The research protocol was approved by the Bioethics Commission of the National University of Life and Environmental Sciences of Ukraine (Protocol No. 049/2025, dated November 4, 2025). The study was conducted and reported in accordance with the ARRIVE guidelines and the Interdisciplinary Principles and Guidelines for the Use of Animals in Research, Testing, and Education of the New York Academy of Sciences, Ad Hoc Animal Research Committee.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Authors' contribution

I. Kepkalo: Formal analysis, funding acquisition, writing – original draft;
M. Khomenko: Software, visualization writing original draft, review & editing;
M. Seba: Funding acquisition, methodology, validation;
N. Svyrydenko: Formal analysis, conceptualization, investigation, supervision, visualization;
T. Lytvynenko: Investigation;
N. Slobodyanyuk: Resources, supervision, validation;
O. Pylypchuk: Methodology, project administration, original draft, writing – review & editing;
M. Sopiha: Methodology, project administration, software;
T. Naumenko: Resources, software, writing – original draft.

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Competing interests

The authors declare no competing interests in this research and publication.

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