SOME INDICATORS OF MILKING ROBOT EFFICIENCY: CASE STUDY ON POLISH FARM WITH ONE-STALL AMS

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Abstract. The development of dairy farms, in addition to improving the potential of animal production, is also associated with advances in milk production methods using technical equipment. The widespread use of automatic milking systems (AMS) on dairy farms across many regions of the world is driving research to assess various aspects of milking with milking robots. A key factor in analyzing the performance of milking robots is the database generated during their operation. This database contains a large number of robot performance parameters and cow-related indicators that are continuously monitored, providing a valuable source of information for further processing. This data processing was undertaken using a database from a Polish farm using a one-stall milking robot as an example. Detailed assessments were made of the relationship between cow milk yield indicators and the number of milkings, cow feed intake rates in AMS during specific seasons, and the efficiency of teat cup attachment to individual teats. Statistical analysis was performed on relevant datasets characterizing the milking robot and the herd of cows. Differences in the effectiveness of attaching teat cups to individual teats were observed, as were differences in the concentrate feed supplied by the robot to cows across the production season. The research results may have a significant impact on further optimization of the milking process using automatic milking systems.

Keywords: automatic milking system, concentrated feed, cow, efficiency, milk yield.

Introduction

Dairy production is one of the most important links in modern agriculture, as it plays a role in the development and stability of the global food sector [1]. Maintaining the high efficiency of the dairy production system depends on access to modern technologies for on-farm milk production. Over the years, the development of cow milking technology has undergone numerous stages of technical advancement, culminating in the automatic milking system [2]. In 1992, the world's first commercially available milking robot was installed on a Dutch dairy farm. However, this crucial stage in overcoming the barriers to technical and technological progress is not a closed chapter. The inclusion of milking robots in the milk collection system has become a driving force for the dynamic development of research on the factors shaping the assessment of the technical potential of automatic milking systems.

Modern research and resulting evaluations of automatic milking systems are developed in many specific areas, including technical [3], technological [4; 5], economic [6], management [7; 8], biological [9], environmental [10], sociological/ethical [11], cow welfare [12], milk quality [13] and others. An important contribution to the evaluation of automatic milking systems is their comparison with conventional milking systems [14; 15] or the effects of linking AMS with pasture-based cow management [16].

Numerous evaluations of milking robot operation on the farm are possible thanks to access to a real-time database generated from information collected during milking. Access to the dataset provides an opportunity for a detailed analysis of selected factors determining the efficiency of milking robot use in real conditions on a dairy farm.

The aim of the research study was to analyze the tasks carried out in the zone of attaching milking cups to the teats of the udder and feed intake by cows at the AMS milking station.

Materials and methods

Observations on the operation of the automatic milking system were conducted on a dairy farm in the Lublin Voivodeship (in eastern Poland). The farm was equipped with a GEA one-stall milking robot, the DairyRobot R9500 model. The automatic milking system worked on the farm, supporting year-round maintenance of the herd of cows in the barn. The annual milk yield of cows on the farm over the past five years was, on average, 9,450 liters per cow, i.e. more than the average milk yield of cows in Poland [17]. The systematic increase in the milk yield of cows on the farm over a five-year period enabled exceeding the level of 10,000 liters of milk per cow per year during the research period.

The data used in the analysis were collected from the milking robot daily use. The data from the robot IT system database included information on milk production on the farm, including the amount of milk per single milking, the average amount of milk obtained per day from one cow, the average number of cow milkings per day, the number of lifts of the robot arm, the feed dispensed during one milking session, and the daily amount of total milk obtained. The dataset was the basis for analyzing the effectiveness of the automatic milking system.

Detailed data from the milking robot data collection and monitoring system were obtained, with the farm owner's permission, during several visits to the dairy farm in 2024 and 2025. The scope of the data obtained from the robotic computer was clearly defined to achieve the analysis objective: to study the relationships between factors characterizing the efficiency of work and the use of the milking robot. The analysis of the milking robot usage also included data on the amount of concentrate consumed by cows during milking. The variation in the concentrated feed intake across seasons was thoroughly evaluated. This type of analysis is not a typical line of inquiry, as the amount of feed consumed by cows is assessed relative to their lactation period and daily milk yield.

The results from this part of the study, taking into account different categories of milk yield, milking, and feed consumption, were subjected to a statistical analysis of variance, taking into account a significance level (α) of 0.05.

The process of attaching milking cups to udder teats in a herd of dairy cows operated by a farm milking robot was also evaluated in detail. The results of observations on the operation of the milking cups were also evaluated using analysis of variance to assess the significance of variation in the number of attempts made when setting the milking cups according to their relative position. In this case, the statistical analysis was extended to include the determination of homogeneous groups using the Tukey test.

Results and discussion

Over the two-year period, a variable number of dairy cow herds were observed, ranging from 44 to 58. On average, 2.5 milkings per cow took place per day. Such information helps us confirm the consistency of the robot milking process, supporting udder health and optimal lactation performance. During the observation period, an average of 1,413 liters of milk was recorded per herd per day, translating to approximately 28 liters per cow per day. These results are comparable and similar to those achieved on other farms equipped with milking systems based on milking robots [18].

Based on the collected dataset, Figure 1 shows the associations between the average daily number of cows milked in the herd and their daily milk yield. Continuing this thread of analysis, Figure 2 shows the amount of milk milked at once, depending on the number of milkings for individual cows during the day.

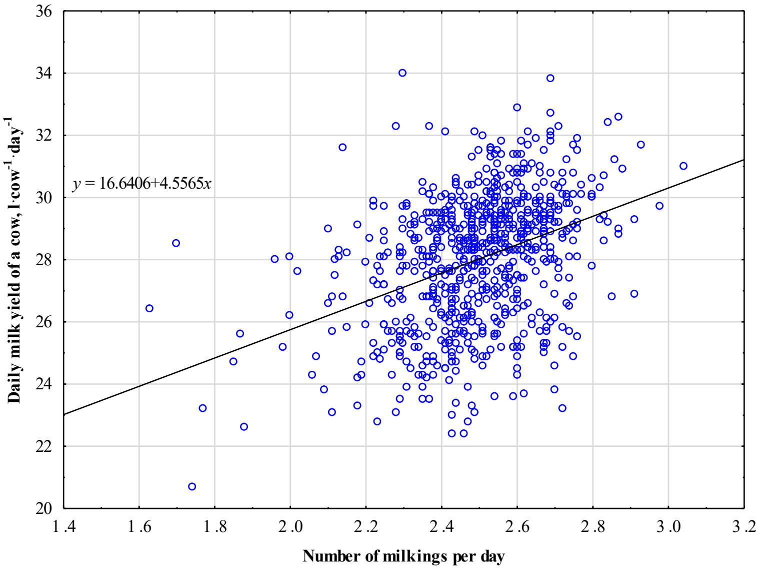

Fig. 1. **Amount of milk milked per day per cow depending on the number of milkings per day**

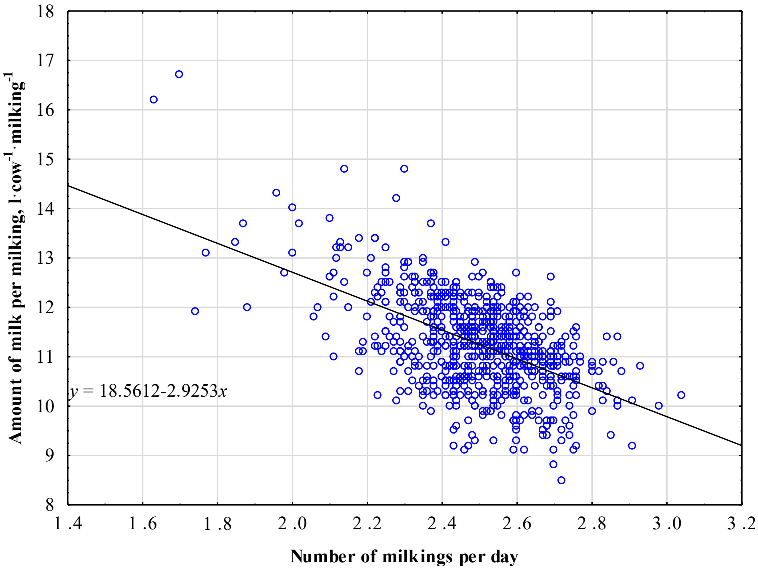

Fig. 2. **Amount of milk per milking per cow depending on the number of milkings per day**

The course of changes in Figure 1 confirms the previously identified relationship, indicating that milk production per cow increases with the frequency of milking during the day [19]. As the number of milkings of individual cows increases, the amount of milk per milking decreases (Fig. 2). If an increase in milking frequency is accompanied by a decrease in the time intervals between the cow's subsequent visits to the robot, then a smaller amount of milk accumulates in the cow's udder before each subsequent milking. Such observations on the effects of using a milking robot are part of the discussion on assessing milking frequency, which has been developed over many years for conventional milking methods. In general, dairy farms with different types of conventional milking systems are dominated by twice-daily milking, for which triple milking remains an alternative. These two alternative approaches to milking organization generate questions about differences in the achieved milking and milk yield of cows, the daily workload and time per milking, as well as differences in energy and water consumption per litre of milk [20] and the costs incurred. An automatic milking system can be included in this discussion of evaluation indicators that account for milking frequency. In detailed studies of milking robots, electricity consumption and water consumption per liter of milk are evaluated [21], which are linked to the number of milkings per cow per day. In this way, the premises for assessing the optimal milking frequency are created, based on a combination of the increase in the amount of milked milk (along with the increase in milking frequency – Fig. 1) and the consumption of energy, water, and chemicals per liter of milked milk, in accordance with the frequency of milking.

One of the more complex tasks performed at a milking robot station is to locate the teats of a cow and attach milking cups to the teats. An analysis of data collected over one month (from 1 to 30 November 2024) showed that the robot performed a total of 26073 tasks related to setting up milking cups, with 4526 visits by cows to the robot milking station recorded. In total, 12,175 tasks (including repetitions) were performed on the front pair of teats, while the robotic arm had to rise 13,898 times to the rear pair. It can be noted that the robot made many more attempts to attach cups to the back quarters of the udder during operation than on the front quarters. This difference in the study period was 1723 repetitions, which, when converted, represented more than 14% more attempts to raise the milking cups onto the rear teats than onto the front teats of the udder. Such a situation (comparison) confirms the results of observations by other authors [22], indicating that it is easier to put milking cups on the front teats compared to the rear ones.

An extension of the problem of the ease/difficulty of attaching milking cups to udder teats is to determine, based on the information collected in the robot database, the average number of cup lifts per cow visit to the robot's milking stall. Under ideal operating conditions, the number of attempts to connect the milking cups should be 4, or 1 per teat. The average number of cup lifts per cow visit to the milking stall was calculated by dividing (for the accepted period of time) the sum of cup lifts into teats at the front and teats at the back by the number of cow visits to the stall. On the farm with the robot milking machine included in the study, the number of trials per milking of a single cow was 5.76, indicating that the milking cup arm made more unsuccessful approaches than the desired conditions (four approaches to installing four milking cups). The presented calculation result may indicate an incorrect angle of the rear teats. In many dairy cow herds, there is also the problem of the lack of proper selection of cows in terms of optimal udder shapes and heights, with well-spaced teats of the appropriate length. The results of our own study confirm the possibility of problems with putting milking cups on the teats of udders, also indicated in the literature [23], due to the distorted structure of the udder of some cows, difficult access to teats (especially the rear teats), and excessive nervousness of some cows during the placement of milking cups on teats. Additional lifting attempts are not only a waste of time when other animals do not have access to the milking robot but can also cause additional stress for the milked cow [24]. As a consequence, this may lead to a decrease in the production rates of some animals, which in turn affects the dairy farm production results.

For the period considered (one month), a variance analysis was performed on the number of attempts to connect milking cups to cow udder teats in the herd for the variable "teat position". The analysis of variance showed that the difference in the number of attempts to connect milking cups to the front and rear teats was significant ($p < 0.05$). Significant differentiation ($p < 0.05$) was also observed for the number of attempts to connect the milking cups for the variables "day of the month" and "cup number". The "cup number" option includes all cups that are connected to udder teats. In this case, Tukey's test indicated three homogeneous groups regarding the number of attempts to connect milking cups. The results indicated the need to account for differences in the analysis and interpretation of data characterizing the effectiveness of attaching milking cups to the teats of cows operated by a milking robot.

Operating cows on the milking stall of a milking robot, in addition to connecting milking cups, also includes the dispensing of concentrated feed. Implementing this task can also yield valuable insights. This information primarily concerns the amount of feed that cows consume per day, in line with their production indicators. On the farm with the evaluated milking robot, the amount of concentrated feed consumed by cows was compared across seasons. A total of two years was included in the data analysis. The highest amount of feed given to cows per day was observed in spring (3.84 $kg \cdot cow^{-1}$) and winter (3.80 $kg \cdot cow^{-1}$). On the other hand, the lowest amount of concentrated feed given to cows per day was identified in summer (3.22 $kg \cdot cow^{-1}$). The analysis of variance showed that the variation in the amount of feed taken by cows across the selected seasons was significant ($p < 0.05$). The results of our own research are consistent with those of other authors [25], who reported that cows consume 3-5 kg of concentrated feed per cow per day using a milking robot. This study also highlights variation in the amount of feed taken in the following months; in our study, however, we accounted for seasons as a comparative baseline. Based on 2 years of data, including total concentrated feed consumption in each season, this consumption was compared between seasons on the farm studied. The total amount of concentrated feed used (given to cows in the milking robot) in winter and spring was more than 9000 kg, i.e. less than 15% higher compared to the amount of concentrated feed given to cows in the milking robot during the summer and autumn. The data analysis thus indicated seasonality in the demand for concentrated feed on the dairy cow farm over a 1-year period. Regardless of seasonal differences in the demand for concentrated feed, full access to this feed for animals is crucial, as it affects cow behaviour and production indicators [26].

Conclusions

Studies have shown the need to account for increased feed consumption during the cold months, which helps provide animals with better conditions to meet their additional energy needs. Information on the demand for concentrated feed directly translates into costs for the farmer and into better adaptation of mixtures to meet animal energy needs.

An important aspect of evaluating the use of a milking robot is selecting animals with appropriate udder anatomy and behavioural characteristics. Eliminating the sources of stress of cows during milking and striving to achieve a rational milking time, often extended by additional attempts to connect milking cups to udder teats, are important prerequisites for improving the milk harvesting system with a milking robot.

Acknowledgements

We would like to thank the owner of the farm with the milking robot for the opportunity to conduct the research and for access to data on the robot operation and to characterize the milk production area.

Author contributions

Conceptualization, M.G.; methodology, M.G. and S.M.; software, S.M.; validation, M.G. and S.M.; formal analysis, M.G. and S.M.; investigation, S.M.; data curation, M.G. and S.M.; writing – original draft preparation, M.G. and S.M.; writing – review and editing, M.G.; visualization, M.G. and S.M.; project administration, M.G. and S.M.; funding acquisition, S.M. All authors have read and agreed to the published version of the manuscript.

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