Use of a robotic milking system by cows of different genotypes reared in a silvopastoral system

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Abstract

The robotic milking system (RMS) is unique in its ability to operate without human intervention. It allows cows to choose when and how often to be milked during the day, benefiting animal health and welfare. However, specific technical indicators for RMS incorporated into pasture-based production systems are still being established. Therefore, this study aimed to analyze the feasibility of integrating robotic milking in a silvopastoral dairy production system with cows of different breeds. The experiment was carried out at Embrapa Pecuária Sudeste, São Carlos, Brazil (22°01'S, 47°53'W, 860m), for 92 days. Sixty-six lactating cows of Holstein (HO, n=21), HJ crossbred (1/2 Holstein × 1/2 Jersey; HJ, n=24), and HX crossbred (≥3/4 Jersey on Holstein base; HX, n=21) breeds were observed. Cows were intensively grazed in a silvopastoral system with voluntary and unrestricted access to the RMS. Data from 9,305 milkings were analyzed (ANOVA; R-Studio; α=5%). HO and HJ cows had a higher daily milk yield than HX cows ($P<0.05$). The HO and HJ cows had a longer daily milking time ($P<0.05$), which was attributed to the higher daily production per animal. There was no significant difference in milking frequency between the genotypes ($P>0.05$). Daily milk yield, daily milking time, and milking frequency were positively and significantly correlated ($P<0.0001$). The results indicate that cows with higher milk yields have spent more time in the milking box. Furthermore, no evidence suggests that more productive cows visit the milking robot more frequently in a pasture-based system.

Keywords: precision livestock farming, automatic milking, milking duration, animal welfare, dairy cows

Introduction

The automation of the milking parlor on dairy farms aims to standardize operations, streamline procedures, and reduce errors by implementing efficient, controlled systems. In this context, there has been a growing interest in robotic milking systems (RMS), which are characterized by their ability to operate without human intervention. RMS allows cows to autonomously choose the best times for milking and establish the daily milking frequency, which benefits animal health and welfare (Tse et al, 2017). The adoption of

RMS aims to improve milking efficiency, increase the number of cows milked per hour, reduce milking time, and increase milk production without compromising animal welfare (Botega et al, 2008). Additionally, RMS allows for the expression of natural cow behavior, allowing the animal to feed, rest, ruminate, and be milked at any time of the day, as needed (Franco Neto & Lopes, 2014).
Currently, the use of robotic milking in confinement and semi-confinement systems is now a reality. The number of studies on the use of RMS has been gradually increasing. The majority of studies have focused on the effects of this type of milking on the health, production, behavior, and feed intake (Paddick et al, 2019; Schwanke et al, 2019; Jerram et al, 2020; Solano et al, 2022). Given its operational characteristics, RMS appears to be an interesting alternative for use in pasture-based dairy production systems as well. However, specific technical indicators for this reality are still being defined in the scientific literature. Therefore, the objective of this study was to analyze the feasibility of integrating robotic milking into a silvopastoral dairy production system with cows of different breeds.

Material and Methods

Bioethics

The present study was approved by the Ethical Committee for the Use of Experimental Animals of Embrapa Pecuária Sudeste (CEUA Certificate PRT No. 06/2022).

Animals, housing, and diet

The experiment was conducted at Embrapa Pecuária Sudeste, located in São Carlos-SP, Brazil (22°01'S, 47°53'W, 860m). The climate of the site is characterized as altitude tropical (Cwa), according to Köppen-Geiger. The experimental period was 92 days, from June to September 2022. Throughout the experiment, data were collected from 66 dairy cows belonging to the pure Holstein (HO; n=21) and Jersey × Holstein cows, with the latter represented by two different genetic groups: HJ crossbred: 1/2 Holstein × 1/2 Jersey (n=24), and HX crossbred: ≥3/4 Jersey on Holstein base (HX; n=21).

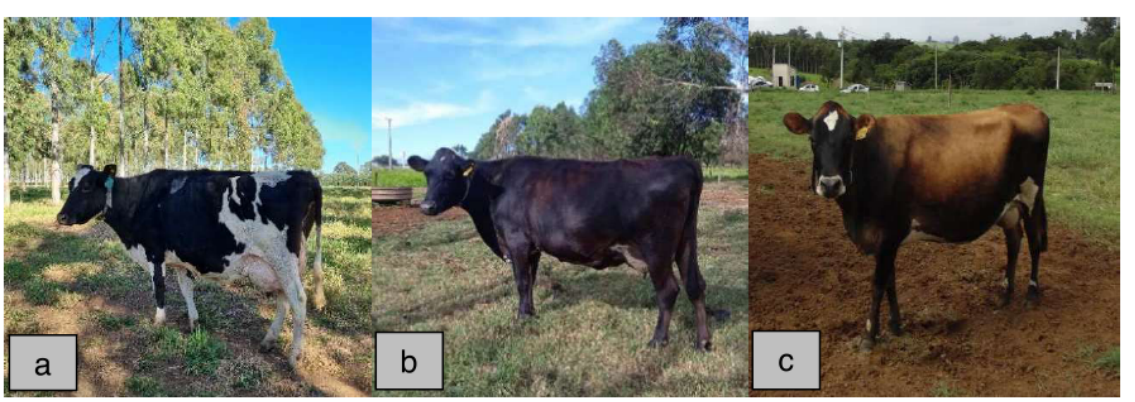

Figure 1: Representative images of animals from the genetic groups used in the experiment. (a) Holstein-HO animal, (b) Jersey × Holstein-HJ animal: 1/2 Holstein × 1/2 Jersey, (c) Jersey × Holstein-HX animal: ≥3/4 Jersey on Holstein base.

The animals were kept in a silvopastoral system (24 ha) under intensive rotational grazing with *Urochloa brizantha* cv. Paiaguas grass. The system consisted of *Corymbia citriodora* eucalyptus trees planted in a single line from east to west, with a spacing of 20 m between rows and 3 m between plants. The trees had an average height of 15.6 m during the trial. In addition to access to the grazing area, the animals received a daily ration of concentrate according to milk production and were supplemented with corn silage during the winter. Water and mineral supplements were provided *ad libitum*.

Milking system and data access

Milking was carried out voluntarily using a robotic milking system (RMS) with the DeLaval VMS™ V300 automatic system adjacent to the grazing area. The distance between the RMS and the centroid of the grazing area was 160 m (min:50-max:365 m). The RMS had a milking box accessible 24 hours a day, except for 120 minutes daily reserved for self-cleaning and repairs, if necessary. The cows had equal access to the milking box and could move freely between the grazing area and the RMS.

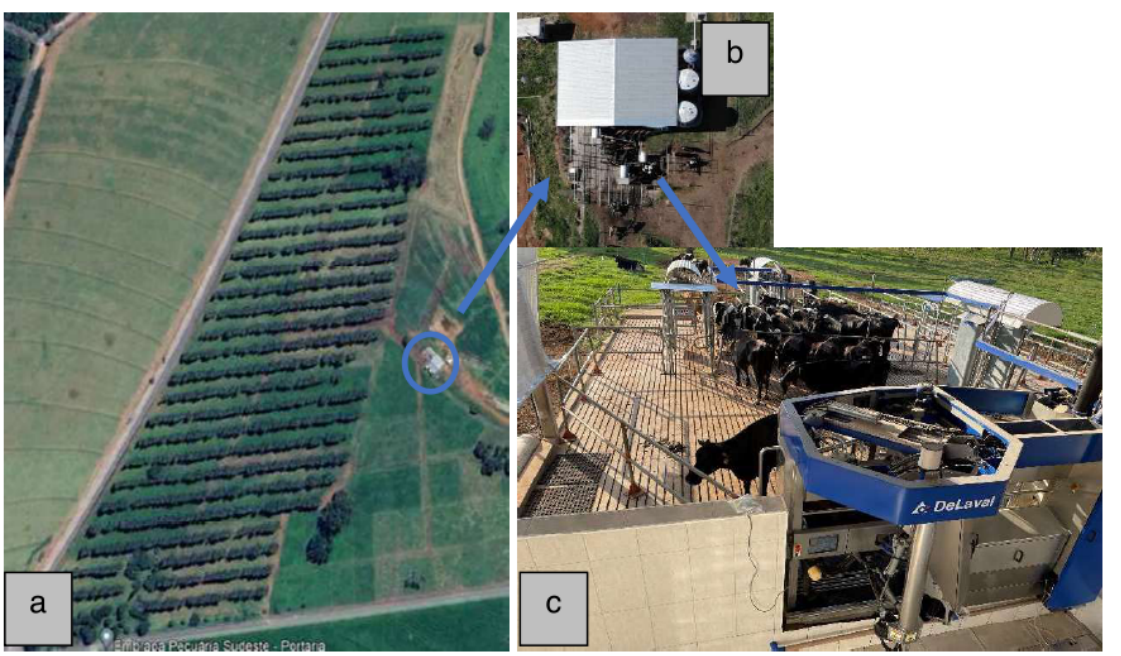

Figure 2: (a) Satellite image of the silvopastoral system used for intensive rotational grazing, (b) aerial image of the facilities of the robotic milking system, (c) milking parlor with the milking box in the foreground.

Each cow was identified with a unique RFID ear tag that was read by the sensor at the entry gate. After identification and authorization, the automatic gate directed the cow to the milking box. The pre-milking, milking, and post-milking processes were then performed automatically by robotic arms. During milking, the system dispensed a specific amount of concentrate for each animal based on its production. The concentrate provided during milking was used to meet nutritional requirements while also providing positive reinforcement to the animal in the milking process, facilitating conditioning. Through a user interface, the RMS provided access to information that was processed, analyzed, and made available as reports. During the experiment period, data related to 9,305 milkings

were recorded. The variables of interest included daily milk yield (DMY), daily milking time (DMT), and milking frequency (MF).

Statistical analysis

The data were assessed for normality of residuals using the Shapiro-Wilk test. Subsequently, mean values were subjected to multiple comparisons using ANOVA. Linear correlation coefficients were calculated using the Pearson test. For all analyses, R-Studio was utilized, and a significance level of 5% ($P<0.05$) was adopted. Correlation coefficients were categorized as strong ($r>0.68$), moderate ($0.36<r<0.67$), or low ($r<0.35$) based on the estimated values (Taylor, 1990).

Results and Discussion

Mean analyses showed that HO and HJ animals had higher production than HX animals (Table 1). These results are consistent with previous findings where purebred Holstein and half-bred Holstein cows showed higher daily milk production than other genotypes (Ludovico et al, 2019). The difference in milking time between HO and HJ compared to HX cows was significant, with animals with higher daily production requiring more time to milk. However, there was no significant difference between genetic groups in the number of visits to the milking box. These results contradict those of Córdova et al (2020), who reported that higher-producing cows in confinement sought to milk more frequently throughout the day.

The discrepancy in results may be due to the type of management, as previous experiments have shown that pasture-raised cows tend to visit the RMS less frequently (Svennersten-Sjaunja et al, 2000). Possibly, the greater distance to be traveled by pasture-raised animals compared to a confined animal system (e.g., free stall or compost barn) serves as a deterrent for more frequent voluntary visits to the milking system. Nevertheless, the frequency of milking observed in the present study did not result in an increased incidence of mastitis (data not shown). If it does not compromise the herd's health status or the animals' welfare, reducing visits to the milking parlor is economically beneficial. High milking frequency is associated with higher feed costs, higher electricity and water costs, higher waste volumes, and higher susceptibility of teats to wounds and traumas (Erdman & Varner, 1995; Dahl, 2005). However, further studies are needed to ascertain the effects of different daily milking frequencies in RMS. Previous studies have shown that an increase in daily milking can result in increased production (Ferland et al, 2016), reduced fixed operating costs, reduced udder contamination, and improved animal comfort (Amos et al, 1985).

Table 1: Means (± standard deviation) of daily milk yield, milking time, and frequency of visits to the robotic milking of cows raised in a silvopastoral system

Breed	Daily milk yield (kg)	Daily milking time (min:sec)	Milking frequency (milkings/cow/day)
HO	25,32±9,35^{A}	15:55±6:59^{A}	2,06±0,56
HJ	25,77±9,34^{A}	15:49±5:33^{A}	2,09±0,49
HX	20,74±9,28^{B}	15:03±5:33^{B}	1,96±0,51

HO: Holstein; HJ: 1/2 Holstein × 1/2 Jersey; HX: ≥3/4 Jersey on Holstein base
(A, B) indicate significant differences in the same column ($P<0.05$)

There was a significant correlation between the variables studied (P<0.0001), as shown in Figure 3. All correlations were positive, indicating an association between DMY, DMT, and MF, with a simultaneous increase in magnitude between variables but with different intensities. A moderate correlation was observed between daily milk yield and daily milking time (0.47). Strong correlations were found between daily milk yield and milking frequency (0.69), and between daily milking time and milking frequency (0.73) (Taylor, 1990).

The positive correlation between DMY and DMT supports the findings of Reinemann & Davis (2002), who observed a simultaneous increase in the average milk production and milking time in Holstein cows. This association may be due to a physiological limitation in the instantaneous increase of milk flow through the teat cistern, either anatomical or endocrine, during the milking process. However, this is a trait that can be addressed in genetic improvement programs, as ~~the~~ milk flow rate has a heritability of 0.43 to 0.52 (Pedrosa et al, 2023).

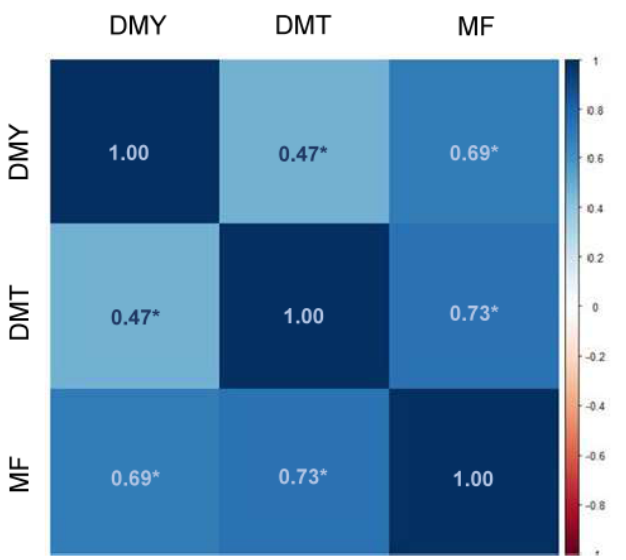

Figure 3: Pearson correlation matrix between the studied variables. Values range from -1 to 1, where 1 indicates perfect positive correlation, -1 indicates perfect negative correlation, and 0 indicates no correlation. DMY: Daily Milk Yield (kg); DMT: Daily Milking Time (min:sec); MF: Milking Frequency (milkings/cow/day). *P<0.0001

The estimated total daily use of the robotic milking system during the experimental period was approximately 17 hours. For every 66 cows, there would be 19 hours of system use and 5 hours of equipment downtime, including time ~~required~~ for cleaning and repairs. This demonstrates the possibility of increasing the number of lactating cows to be milked by between 18 and 20 animals, regardless of the genotype studied, without compromising the functioning of the robot or the use of the RMS by the pastured-raised cows. Moreover, the strong correlation between DMT and MF indicates that the cow is more likely to remain in the milking stall when the animal seeks milking more frequently. This result is likely related to higher individual production (Devries et al, 2005).

Conclusions

The results indicate that more productive cows spent more time in the milking box, especially the Holstein and the 1/2 Holstein × 1/2 Jersey crossbred cows. Contrary to expectations, higher-milk-yield cows did not increase the number of visits to the robot. Longer walking distances, which are characteristic of pasture-based production systems, may influence the search for automatic milking. This highlights the importance of adapting management practices to the specific characteristics of the production system. Furthermore, the use of RMS allows ~~for~~ the evaluation of new traits, especially those that can be further studied from physiological and genetic perspectives. It may have significant potential for use in animal breeding programs and may be economically relevant for pasture-based dairy production systems.

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