

Correlations between milking characteristics and behavior of cows milked in robotic systems

Correlações entre características de ordenhabilidade e comportamento de vacas ordenhadas em sistemas robotizados

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Highlights

Increasing milk flow and decreasing box time enhance milking efficiency.

Reducing incomplete milkings leads to shorter handling time and box time.

No correlations between milking characteristics and behavior.

Abstract

The objective of this study was to analyze the correlation between milking characteristics and the behavior of cows in automatic milking systems. Data were collected between September 2019 and March 2020 from two commercial dairy herds located in Minas Gerais, Brazil, which use an automatic milking system (AMSTM, DeLaval, Tumba, Sweden). The dataset comprised 68,896 observations from 542 primiparous and multiparous cows of Holstein and crossbred (Holstein × Jersey) breeds. Daily milking characteristics,

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including milk flow rate (FR), time spent in the milking box (BT), and milking efficiency (ME), were recorded, along with behavioral traits such as milking handling time (HT), incomplete milkings (IM), and kicks. To assess the relationships between these traits, a bivariate correlation analysis was performed using Pearson's correlation coefficient, executed with the statistical software SPSS version 22. The results revealed moderate negative correlations between FR and BT, ME and HT, and BT and ME. Conversely, a strong positive correlation was observed between FR and ME. A high positive correlation was identified between BT and HT, a moderate positive correlation between ME and milk yield, and a weak positive correlation between HT and IM ($P < 0.01$). No significant correlation was found between milking frequency and kicks or incomplete milkings.

Key words: Automatic milking system. Automation. Milking efficiency. Temperament.

Resumo

Objetivou-se analisar a correlação entre características de ordenabilidade e de comportamento de vacas ordenhadas em sistemas de ordenha automáticas. Os dados coletados, foram referentes ao período de setembro de 2019 a março de 2020, oriundos de dois rebanhos leiteiros comerciais localizados no Estado de Minas Gerais, nos quais utilizam sistema de ordenha automática (AMSTM, DeLaval, Tumba, Suécia), contêm 68.896 observações, de 542 vacas primíparas e multíparas da raça Holstein e mestiças (Holstein x Jersey). Os registros diários de características de ordenabilidade como fluxo do leite (FL), tempo no box (TB) e eficiência na ordenha (EO); bem como características de comportamento: handling time na ordenha (HT), ordenhas incompletas (OIN) e coices (COI) foram avaliadas por análise de correlação bivariada pelo coeficiente de correlação de Pearson, utilizando-se o programa estatístico SPSS versão 22. As correlações foram negativas moderadas entre FL e TB; EO e HT; bem como TB e EO; e positiva e alta entre FL e EO. Correlação positiva e alta foi encontrada entre TB e HT; positiva e moderada entre EO e PL; e positiva baixa entre HT e OIN ($P < 0,01$). Não houve correlação entre a frequência de ordenha (FO) com COI e OIN.

Palavras-chave: Automação. Eficiência de ordenha. Sistema de ordenha automático. Temperamento.

Introduction

In Brazil, around 50 automatic milking systems (AMS) have been implemented since their initial installation in Castro - PR, in 2012 (Silvi et al., 2018; Toloi, 2017). This trend towards greater investment in milking parlor robotization is primarily driven by the growing herd sizes, escalating operational costs, and limited workforce training (Silvi et al., 2018). With milk production projected to reach between 42.0 and 46.8 billion liters by

2029 (Ministério da Agricultura, Pecuária e Abastecimento (MAPA), 2020), a further rise in the adoption of this technology is anticipated.

AMS technology presents new challenges for cows, necessitating a reevaluation of inherent animal traits to ensure efficient equipment use. These systems are equipped with sensors capable of collecting and storing a large amount of data, including milk flow rate (FR) and time spent in the milking box (BT), which are characteristics that define

milkability (Carlström et al., 2013; Gäde et al., 2006) and milking efficiency (ME) (Heringstad & Kjøren Bugten, 2014; Wethal & Heringstad, 2019). Additionally, incidents like kicks and incomplete milkings (IM) provide valuable objective information on behavioral traits for the evaluation of individual cow efficiency (Wethal & Heringstad, 2019).

Effective use of an automatic milking system requires docile, high-yield, and fast-milking cows that exhibit motivation and independence in visiting the robot (Jacobs & Siegford, 2012; Santos et al., 2018). Conversely, restless cows prone to kicking during milking or having morphologically incorrect udders extend handling time (HT) and impede the robotic arm's teat cup attachment, both considered undesirable traits (Carlström et al., 2016; Stephansen et al., 2018).

Globally, numerous studies have explored the performance of cows in AMS systems, revealing correlations between milking characteristics and behavior based on data collected from the AMS (Carlström et al., 2013, 2016; Wethal & Heringstad, 2019). Milkability encompasses the assessment of performance during milking, including characteristics like FR and BT (Gäde et al., 2006), as well as milking efficiency (Vosman et al., 2018). Behavioral traits comprise handling time¹¹ during milking, incomplete milkings, and kicks (Wethal & Heringstad, 2019).

However, in Brazil, there is a scarcity of research results linking these parameters to improved milking performance (Cardozo,

2017; Córdova et al., 2018). Hence, it is imperative to conduct research in this area, given the growing application of robotic milking in Brazil. Understanding milking characteristics and behavior, along with their correlations, can facilitate the generation and expansion of knowledge of Brazilian conditions, aiding technicians and producers in selecting more efficient and healthier cows for voluntary milking systems.

In light of these considerations and the significance of the subject, this study aims to analyze the correlations between specific milking characteristics and the behavior of dairy cows milked in robotic milking systems within two commercial herds located in Minas Gerais.

Material and Methods

Data source and collection

The data for this study were sourced from two commercial dairy herds employing automatic milking systems (AMSTM, DeLaval, Tumba, Sweden). The data collection period encompassed the months from September 2019 to March 2020, which corresponds to the rainy season of the year. The first of these dairy herds is equipped with six AMS units utilizing a "feed first" guided traffic system. This herd is situated in the Triângulo Mineiro/Alto Paranaíba region of Minas Gerais, Brazil. The farm follows an intensive dairy farming system and accommodates all lactating cows in free-stall sheds. The cows' daily routine

¹¹ Handling time (HT): includes the time from the cow entering the milking box until the start of milking (time for teat detection, washing, stimulation, and pre-milking) + the time after milking until the entrance gate be opened to allow the next cow to enter (Carlström et al., 2016); Handling time (HT): time in the AMS before and after milking, in minutes (Wethal & Heringstad, 2019).

involves visiting feeding areas, followed by resting areas, and subsequently the AMS unit, facilitated by a combination of single-way pre-selection gates. Primiparous cows do not undergo AMS training prior to calving; rather, they are introduced to the system approximately 15 to 20 days postpartum. During this initial period, these cows are milked conventionally three times a day. Following this acclimation period, they are led to the waiting room and subsequently guided to the robot for their first milking experience within the AMS. These initial milking sessions are conducted under the supervision of an employee, who provides heightened visual oversight during the subsequent days. Additionally, in the event of any delays in milking permissions, these cows are collected and guided to the AMS unit as needed.

The second herd comprises four AMS that adopt milk-first guided traffic. This herd is situated in the center-west region of Minas Gerais. The farm employs an intensive dairy farming system, housing all lactating cows in compost barn-type sheds. Cows must pass through the robot initially to access the feeding lane and then return to the rest area. In the case of primiparous cows, they do not receive training in the AMS before calving. Instead, they are introduced to the AMS on the first day postpartum, guided by an employee to the waiting room, and subsequently, guided to the robot for their first milking. From that point onward, their management follows the same protocol as that adopted in the first herd.

A total of 148,171 daily milking records were employed, involving 603 cows from two genetic groups. In the feed-first herd, 195 cows were of the Holstein breed, and 167 were crossbreeds (Holstein

× Jersey) with varying calving numbers. In the milk-first herd, the data pertained to 241 Holstein cows, including 122 primiparous and 119 multiparous cows. The raw (initial) data set was processed using DelPro™ software (DeLaval, Tumba, Sweden).

Data treatment and analysis

The data selected for analysis were exported from the software into Microsoft Office Excel table reports. In data collection, following the methodology of Carlström et al. (2013), AMS reports were utilized. These reports contained information regarding: **a) Cow identification:** cow's number, days in milk (DIM), calving number (1 and more than 1 calving), and genetic group; **b) Milking data,** such as the date and time of entry (start time) and exit (end time) of each visit, milking time (minutes), last milking interval (MI; hours), and milking frequency (MF); **c) Information on:** milk yield (MY; kg), average milk flow rate (AFR; kg/min), and peak milk flow rate (PFR; kg/min) in each udder quarter; and **d) Problems during milking:** including the number of incomplete milkings (IM), observation of kicks, and teats not found.

During data editing, records with times in the box less than 1 or more than 20 min and handling times below 0.3 and above 15 min were excluded. Additionally, records without observations of milk production were eliminated. Records that deviated significantly from normal patterns in terms of variation in milking interval, box time, milk yield, average and peak flow rates were also excluded, as were empty cells for these characteristics (Carlström et al., 2016). The lactation period was considered to be between 5 and 305 days after calving. To aggregate production

and milking speed data, the methodology of Wethal and Heringstad (2019) was applied. This method considered all records in which milk yield was ≤ 50 kg in total per milking and ≤ 13 kg per udder quarter per milking. It also took into account the maximum average milk flow rate of 3 kg milk/min and the maximum peak milk flow rate of 4 kg milk/min in any of the udder quarters.

The set of milking records was summarized as one observation per cow per day. This summary included daily averages of box time, milk flow rate, milking efficiency, handling time, and milking intervals (Wethal & Heringstad, 2019). The daily sums of milking frequency, kicks, and incomplete milking were also calculated. Subsequently, statistical analysis was performed.

The following milkability characteristics were analyzed based on AMS records:

a) Average and peak milk flow rates: following the methodology of Wethal and Heringstad (2019) (kilograms of milk per minute of milking), measured for each quarter of the udder in one milking. The average values of milk flow rate and quarter peaks were used separately to obtain a single record per milking for each of these two characteristics. Therefore, cows with fewer than four udder quarters milked had lower milk flow.

b) Box time: the time, in minutes, from the cow's entry into the milking unit until her exit, calculated as the difference between the start and end time (Løvendahl et al., 2011).

c) Milking efficiency: milk production per unit of total time; the value was calculated using the total milk yield (kg) of the four quarters in each milking, divided by box time (min), following the methodology described

by Heringstad and Kjøren Bugten (2014).

Additionally, the following variables were analyzed:

a) Milking time: calculated in minutes, following the methodology of Carlström et al. (2013). This variable was calculated as the ratio between milk yield (kg) and average milk flow rate (kg/min) for each udder quarter separately. The flow was measured only during the time in which the quarter was actually milked, with 30 s being added as a constant to the cup attachment time. According to Carlström et al. (2016), the cow's milking time is defined as the longest milking time of the four quarters, i.e., the time from the beginning of milking until the milk flow ends when the last teat cup has been removed.

b) Milking interval: the time, in hours, obtained from the AMS, as the difference between the start time of the current milking and the start time of the previous milking (Carlström et al., 2013).

c) Milking frequency: also obtained from the AMS, defined as the number of milkings per day (Wethal & Heringstad, 2019).

Three behavioral characteristics were analyzed, as follows:

a) Milking handling time (HT): the difference between box time and milking time (in minutes), obtained from the longest time of the four quarters. This yielded a record for each milking (Carlström et al., 2013).

b) Incomplete milkings: the number of daily milkings with at least one quarter recorded as an incomplete milking.

c) Kicks: AMS sensors recorded the number of premature or unexpected removals of the liners from each quarter of the udder during milking (Carlström et al., 2016).

Incomplete milking is defined by the DeLaval AMS as when the current milk yield falls below 70% of the expected production in any quarter of the udder, based on previous milkings in the last 24 h (Wethal & Heringstad, 2019). Instances where the robot was unable to detect at least one teat of the four quarters were included in the count of incomplete milkings (IM). Although kicks during milking can lead to incomplete milkings, we chose to distinguish between these two phenomena, as per Carlström et al. (2013, 2016). Milking intervals between 5 and 30 h were considered. The characteristic was then defined as binary (0 or 1) for each milking and summarized across all milkings per day. If a cow had one or more incomplete milkings in each milking session and was milked three times daily, this would be recorded as three incomplete milkings.

A kick is defined here as any removal or dropping of the teat cup from the teat of any quarter during a milking session. This characteristic is also binary (0 or 1) per milking and summarized as the sum of milkings per day. A cow that exhibits at least one kick during milking is assigned a kicking record, and if she undergoes three milkings a day, this record is associated with each milking, resulting in three kicks/cow/day. However, due to the low frequency of milkings with kicking records and incomplete milkings, we did not perform analysis of variance, mean difference tests, or analyses that allow for more detailed comparisons. Therefore, a second type of analysis was carried out, summarized as percentages of total observations in milking for each genetic group, calculated using the following formula:

Kicks (%) or incomplete milkings (%) = Number of observations of kicks or incomplete milkings/Total observations per study.

Correlations between milking and behavior characteristics and other measurements obtained from the AMS were analyzed using Pearson's correlation coefficient at a significance level of 1%, in SPSS software version 2. To interpret the Pearson correlation values, we followed the criteria proposed by Bisquerra et al. (2009).

Results and Discussion

The final dataset analyzed consisted of 68,896 observations from 539 cows, including 49,725 Holsteins and 19,171 Holstein × Jersey crossbreds. Table 1 presents the descriptive characteristics of the datasets used in this research.

Table 2 displays the estimated correlations between behavioral and milkability characteristics and other measurements, based on daily observations. Correlations between the three milkability characteristics box time, milking efficiency, and milk flow rate were moderate to very high, ranging from -0.557 to 0.980 ($P < 0.01$). A high positive correlation (0.716) ($P < 0.01$) was observed between milking efficiency and milk flow rate, indicating that they change in the same direction. In other words, as milk flow increases, so does milking efficiency. These results were expected as these characteristics are inherently related, with milk flow rate influencing milking time, defined as the volume of milk passing through the teat sphincter in a given time (Bylund, 2003), and milking efficiency being defined as yield in kg of milk/min and the total occupation time in the AMS (Bakke & Heringstad, 2015). Wethal and Heringstad (2019) reported a higher correlation value of 0.98, leading to their conclusion that milk flow rate holds greater

promise as an indicator for assessing milking characteristics in animals. This assessment is supported by the notion that milking efficiency is a subjective characteristic as it depends on the management of cows during their stay in the AMS. In the current investigation,

we also observed a concordant direction of correlation in these variables, albeit of lower magnitude, which can be ascribed to the sample size that introduces greater variability into the findings.

Table 1

Descriptive characteristics of the datasets obtained from two commercial herds of different genetic groups and calving numbers, which adopt automatic milking systems (AMS) with guided traffic, located in the state of Minas Gerais

Calving number	Genetic group							
	Holstein*				Crossbred*			
	N. of cows	N. of obs.	% KIK obs.	% IM obs.	N. of cows	N. of obs.	% KIK obs.	% IM obs.
Primiparous	110	13.926	11,0	8,8	81	11.032	8,4	7,5
Multiparous	51	9.225	6,2	6,1	65	8.139	9,0	7,6
Total	161	23.151	9,0	7,7	146	19.171	8,7	7,6
	Holstein**							
Primiparous	118	10.759	11,6	6,8				
Multiparous	117	15.815	4,4	10,3				
Total	235	26.574	7,3	8,9				
Grand total	396	49.725	8,1	8,3	146	19.171	8,7	7,6

KIK: milking with kicks; IM: incomplete milkings; Obs.: observations; *: Data from the herd that adopts the feed-first guided traffic system; **: Data from the herd that adopts the milk-first guided traffic system.

Note: there was not enough data to perform analysis variance and means test.

Moderate negative correlations were observed between box time and milking efficiency (-0.557) ($P < 0.01$) and between box time and milk flow rate (-0.564) ($P < 0.01$; Table 2), signifying that these characteristics change in opposite directions, that is, when either milk flow rate or milking efficiency increases, box time decreases. Similar results were reported by Carlström et al. (2013), yet with greater intensity, between milk flow rate and box time (-0.92); and by Wethal and Heringstad (2019), between milking efficiency

and box time (-0.87). In the current study, we observed a similar directional correlation between these variables, albeit with a lower degree of intensity. This reduced intensity can be attributed to the sample size, which may lead to increased variability in the results.

Box time certainly has a greater influence on milking efficiency and capacity in an AMS when compared to milk flow rate and milking time (Carlström et al., 2016). Box time is a key characteristic for evaluating

the efficiency of animals in using the AMS, as it is influenced by the animal's genetics, ensuring efficient milking, in contrast to non-robotic systems where the occupation time is determined by the milker (Wethal & Heringstad, 2019).

Handling time displayed a positive and high correlation with box time (0.664) ($P < 0.01$) (Table 2). Milking time, another measure associated with the time spent in the AMS, had a moderate positive correlation with box time (0.741) ($P < 0.01$). Essentially, when handling time or milking time increases, box time increases as well. These associations were anticipated as milking time and handling

time are components of the total milking time. The correlation between handling time and box time is consistent with values reported by Wethal and Heringstad (2019) (0.64) and lower than those obtained by Carlström et al. (2016) (0.85). According to Carlström et al. (2016), an increase in handling time is linked to the temperament and conformation characteristics of the udder, especially unfavorable teat positioning. Future research may explore handling time as a characteristic contributing to the identification of desirable animals in selection programs based on box time, as it is influenced by behavioral and udder conformation traits.

Table 2

Correlations between traits of dairy cows of different genetic groups and calving numbers, milked by automatic milking systems (AMS) with guided traffic, in two commercial herds located in the state of Minas Gerais

Trait	BT	ME	FR	IM	KIK	HT	MF	AI	MT	MY
Milkability										
Box time (min)	1									
Milking efficiency (kg/min)	-0,557**	1								
Milk flow rate (kg/min/udder)	-0,564**	0,716**	1							
Behavior										
Incomplete milkings (n/cow/day)	0,254**	-0,347**	-0,155**	1						
Milkings with kicks (n/cow/day)	0,017**	-0,031**	0,000	-0,034**	1					
Handling time (min)	0,664**	-0,605**	-0,171**	0,419**	0,062**	1				
Others										
Milking frequency (n)	-0,224**	-0,21**	0,029**	0,001	0,046**	-0,119**	1			
Average milking interval (h)	0,206**	0,058**	-0,006	0,014**	-0,012**	0,072**	-0,580**	1		
Milking time (min)	0,741**	-0,205**	-0,601**	-0,036**	-0,032**	-0,006	-0,192**	0,211**	1	
Milk yield/milking (kg)	0,250**	0,617**	0,225**	-0,226**	-0,028**	-0,201**	-0,241**	0,293**	0,512**	1

BT: box time; ME: milking efficiency; FR: milk flow rate; IM: incomplete milkings; KIK: milkings with kicks; HT: handling time; MF: milking frequency; AI: average milking interval; MT: milking time; MY: milk yield/milking.

** : The correlation is significant at the 0.01 level.

In the present study, we observed a low, positive correlation (0.419) ($P < 0.01$; Table 2) between handling time and incomplete milkings; and a very low, positive correlation (0.062) ($P < 0.01$) between handling time and kicks. This indicates that as the number of incomplete milkings increases, due to the time it takes for the robot arm to locate teats, handling time also increases. However, the correlation between handling time and kicks suggests only a minor increase in handling time due to kicking. Our findings regarding the correlation between incomplete milkings and handling time are consistent with the correlation coefficient of 0.53 reported by Wethal and Heringstad (2019) and lower than the 0.89 reported by Carlström et al. (2016). Therefore, the characteristic of incomplete milkings can serve as an interesting metric for evaluating the productivity of cows, rather than relying solely on milk yield or successful milkings.

Similarly, the correlation between handling time and kicks, while not high, also exhibited a positive direction, with coefficients of 0.56 and 0.50, as reported by the same authors. This can be attributed to the fact that the authors estimated correlations using summarized averages over complete and successive lactations for several years, whereas our study had a smaller sample size with fewer daily records of kicks. Regarding kicks and incomplete milking, crossbred cows had a higher number of observations with kicks, while Holstein cows were more likely to experience incomplete milking (Table 1). In terms of calving number, primiparous Holstein cows and multiparous crossbred cows had a greater number of observations with kicks. The observations of incomplete milking in Holstein cows varied depending on

the calving number, while for crossbred cows, they remained relatively similar.

We also identified moderate, negative correlations between handling time and milking efficiency (-0.605) ($P < 0.01$; Table 2). This implies that as handling time increases, milking efficiency decreases. Similarly, we found moderate negative correlations between milking time and milk flow rate (-0.601) ($P < 0.01$), indicating that as milk flow rate increases, milking time decreases. Furthermore, there was a moderate positive correlation between milking time and milk yield (0.512) and between milking efficiency and milk yield (0.617) ($P < 0.01$; Table 2). This suggests that as milk yield increases, milking time and milking efficiency also increase. In optimizing the milkability of cows in the AMS, it is essential to avoid milkings with kicks and incomplete milking, promote faster milk flow, and achieve higher milking efficiency by minimizing box time and handling time (Wethal & Heringstad, 2019).

According to Carlström et al. (2016), high milk flow is associated with shorter milking times. However, the duration of milking time does not always depend on the amount of milk produced but may be associated with the rate of milk flow. It is possible that cows with lower milk yields and higher flow rates experience shorter box times compared to cows with lower flow rates and higher yields, which may result in longer box times. Further research is needed to evaluate these differences in milk flow and milking speed between the two genetic groups and between herds and to explore any associations with different yields for each quarter of the udder.

Milk flow rate is a critical factor for udder health. Higher rates are associated with

low sphincter tension, which leads to a longer exposure time of the teat canal, increasing the likelihood of intramammary infection (Grindal et al., 1991). A moderate genetic correlation (0.29 and 0.57) was demonstrated between milking speed metrics (milk flow rate, handling time, and box time) and the increase in somatic cell count in milk (Carlström et al., 2016). Positive correlations (0.88) were also found between milking speed and problems related to milk leaking through the teat (Bakke & Heringstad, 2015). As suggested by Santos et al. (2018), when selecting the most efficient animals in the AMS, it is necessary to identify the desirable milking speed rather than seeking the maximum milking speed, which could compromise udder health.

Milking frequency and interval are moderately correlated (-0.580) ($P < 0.01$), i.e., when milking frequency increases, milking interval decreases. This value is significantly lower than that reported by Wethal and Heringstad (2019) (0.99). This difference may be attributed to the data editing process in this research, which excluded observations with milking intervals of less than 5 h and atypical values of time in the box and handling time. Moreover, Wethal and Heringstad (2019), who also conducted data editing, utilized statistical models for complete lactations for each animal, potentially strengthening the correlation between these two traits. According to Wethal and Heringstad (2019) and Carlström et al. (2013), it is essential to consider milking frequency and interval measurements as they can impact critical aspects of milking efficiency. Variations in milking frequency are known to be influenced by factors such as lactation phase, production level, and

individual characteristics (Hogenboom et al., 2019; Santos et al., 2018). According to several studies, milking frequencies are also related to system configuration (De Koning & Van Der Vorst, 2002), cow traffic system (Siewert et al., 2019), box dimensions and group size (Tremblay et al., 2016), feeding (Bach & Cabrera, 2017; Halachmi, 2009), health disorders (King et al., 2018), and the number of AMS units (Siewert et al., 2018).

In the present study, milking frequency and milking interval demonstrated very low or non-existent correlations with kicks and incomplete milkings ($P < 0.01$) (Table 2). This implies that an increase in milking frequency or interval results in an insignificant increase in kicking and incomplete milking. These findings may be associated with the sample size of the current study and the data editing process, which followed the methodology proposed by Wethal and Heringstad (2019). Specifically, milking intervals shorter than 5 h were excluded to avoid considering closely spaced incomplete milkings. Additionally, a shorter milking interval could lead to incomplete milking by reducing milk production in each milking session. In this study, incomplete milkings were defined as milk yield in the current milking session being less than 70% of the expected production in any udder quarter (Wethal & Heringstad, 2019). While the same trends were observed in these variables as in the work of Wethal and Heringstad (2019), the correlations' intensity was lower: milking frequency and kicks (0.16), milking frequency and incomplete milkings (0.23), milking interval and kicks (-0.23), and milking interval and incomplete milkings (-0.70). This discrepancy may be attributed to the sample size, which introduces greater

variation since they used summary metrics for each cow's complete lactation, analyzed as a proportion of occurrence in each lactation.

Nonetheless, research indicates correlations between milking frequencies and intervals and milking behavior, which can be attributed to the handling response (Cardozo, 2017; Cerqueira et al., 2012; Jacobs & Siegford, 2012; Montero, 2014). Discomfort arising from mastitis or sore teats due to increased milking frequency increases the likelihood of liner attachment failures (Rodenburg, 2013). Inflammation-related udder enlargement causes discomfort and pain during milking (Montero, 2014), constraining the practice. Additionally, the combination of increased milking frequency and longer milking duration may lead to a higher presentation of hyperkeratosis score in the teat sphincters (Cardozo, 2017). Kicking occurrences may result from the stress associated with discomfort in the udder in the AMS, which is a consequence of reduced milk flow and the pressure from the vacuum system during the milking's final stages (Cerqueira et al., 2012; Jacobs & Siegford, 2012). Therefore, the frequency of kicking could serve as an auxiliary health indicator, potentially associated with mammary gland infections. This hypothesis warrants further investigation in future studies (Heringstad & Kjøren Bugten, 2014).

Conclusions

In the current investigation, we examined the correlation between parameters that describe milking efficiency and behavioral aspects within AMSs. Milk flow rate and milking efficiency are optimal

factors to promote a faster milking speed and reduced box time. Our findings revealed that handling time exhibits an increase in instances of incomplete milkings compared to milkings with kicks. Future research endeavors may consider dissecting these attributes individually across different stages of lactation, with the aim of characterizing temperament within AMSs.

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