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Original article

The influence of lameness on several automatic milking system variables and reproductive performance indicators in dairy cows

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Abstract

There is an increased interest in using automatic milking systems (AMS) to indirectly assess the welfare of dairy cows, but knowledge on analyzing the association between lameness, milk yield characteristics, and reproductive performance in cows is still insufficient. The main aims of this study were to evaluate the influence of lameness on several AMS variables and reproductive performance indicators during the early stage of lactation and estrus in Lithuanian Black and White dairy cows, as well as to assess the associations between lameness, productivity and reproductive efficiency. A total of 418 milking cows (50.3±1.2 d postpartum) without any apparent reproductive disorder were monitored for hoof health status. Cows were assigned to two groups on the basis of visual locomotion scoring: "non-lame"cows (group 1; 74.20%) and cows presenting "lameness" (lame cows) (group 2; 25.80%).

Productive and milking performances of dairy cows were recorded from 50 to 100 days in milk (DIM) and 1 day after the first estrus. The lameness was predominantly localized on the hind feet (79.60%) and less frequently - on the front feet (20.40%; $p<0.001$). Furthermore, the lameness had a tendency to decrease milk production (4.24%; $p<0.05$) and increase the difference in milk yield between rear and front quarters of the udder (1.20%; $p<0.05$). The frequency of milking (5.19%) was lower in lame cows ($p<0.05$). The lame cows during estrus showed a more pronounced decrement in milk yield and milking frequency ($p<0.05$), and also higher milk progesterone concentration values (1.55-1.76 time's; $p<0.001$), and an increasing number of inseminations (11.69%; $p<0.05$) were observed. The results highlighted that analysis of data from AMS programs can be a successful tool for reducing risk factors related to the effective management of reproductive performance and hoof health of dairy cows.

Key words: dairy cow, lameness, estrus, automatic milking, fertility

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Introduction

Lameness due to foot disorders indubitably represents the third most serious health-related cause of economic loss in the dairy industry after reproduction disorders and mastitis (Booth et al. 2004). Vergara et al. (2014) revealed that lameness is more common among highly productive cows and ranged from 8.7 to 13.4%. Similar findings were noted by Hernandez et al. (2002) who showed that 31% of cows were affected with lameness during lactation; lame cows suffered from hoof lesions (60%), papillomatous digital dermatitis (31%), or interdigital phlegmon (9%). A study conducted by Guccione et al. (2016) reported that foot disorders were mainly localized on the hind feet (73.8%) and less frequently on the front feet (26.2%), whereas in Irish dairy herds 89.6% and 11.8% of cows showed lesions on hind feet and front, respectively (Somers and O'Grady 2015).

Studies of lameness in AMS herds have reported reduced milk yield and milking frequency and also greater daily lying time for lame cows (Bach et al. 2007, Deming et al. 2013, Westin et al. 2016). Borderas et al. (2008) in 578 Holstein cows from 12 AMS on eight dairy farms in Quebec (Canada) estimated that the frequency that dairy cows visit an AMS is related to their locomotory ability, and data from the AMS may assist in the early detection of lameness.

The majority of researchers have observed more prevalent lameness in older cows in AMS milked herds (Bach et al. 2007, Borderas et al. 2008). Moreover, Haskell et al. (2006) reported higher levels of lameness in dairy herds managed under zero-grazing systems compared to grazing herds.

Lameness has negative implications on the reproductive performance of cows (Sogstad et al. 2006). Barkema et al. (1994) stated that lameness prolonged the interval between first service and conception by 3.4 days. Somers et al. (2015) in Irish dairy herds indicated that reproductive efficiency was significantly lower in cows becoming lame during the breeding season and cows lame before and during the breeding season compared to non-lame cows. Lameness is associated with reduced estrus intensity in dairy cows (Walker et al. 2008). Reduced estrus expression in lame cows can be explained by altered time budgets compared with non-lame cows. Lame cows dedicate less time to standing and walking as a consequence of lying down more, thus decreasing the opportunity to express sexual behavior (Walker et al. 2008). The results of a study conducted on a UK commercial dairy farm (Walker et al. 2010) also indicated that lameness can induce an overall reduction of approximately 37% in estrus intensity. The above mentioned findings emphasize that lameness is of critical importance.

Milk progesterone concentration is a relevant regulator of events during the estrus cycle. In dairy cows, progesterone level can be affected by many factors, including cow health status (Spencer et al. 2007, Arndt et al. 2009, Hansen 2011, Boldt et al. 2014).

In clinical practice it is quite complicated for producers to identify cows in the early stages of lameness (Whay et al. 2003). However, such indentification contributes to the prevention of more severe hoof disorders, which cause almost 3 times higher costs than mild hoof disorders (Charfeddine and Pérez-Cabal 2017). The effects on the everyday life of moderately lame dairy cows in loose housing systems indicate that even an early stage of lameness already has a great potential effect on animal welfare (Weigele et al. 2018).

The majority of studies on lameness are based on management systems for this multifactorial disease, land fewer data are available for changes in AMS milking traits in lame cows in relation to fertility and estrus behavior. Thus, we aimed to examine the influence of lameness on several AMS variables during the early stage of lactation and estrus in Lithuanian Black and White dairy cows, as well as to estimate the relationships between lameness, productivity and some reproductive performance indicators.

Materials and Methods

Animal selection

A total of 418 Lithuanian Black and White dairy cows (50.3±1.2 d postpartum) without any reproductive disorders were monitored carefully for hoof health status on a commercial dairy farm.

The ratio between milk fat and milk protein of the inspected cows was from 1 to 1.5. The average somatic cell concentration in the milk of the cows did not exceed 100,000 cells/ml. Electrical conductivity of the milk fluctuated from 4.0 mS/cm to 5.0 mS/cm. Milk somatic cell count and electrical conductivity were not analyzed separately for groups of cows. Based on the primary data, we did not notice any difference between the groups. The selected cows had no apparent disease or veterinary treatment during the 4 weeks before data collection. Corrective hoof trimming of cows had been done 2 weeks before data collection.

The majority of the cows were between their second and fourth lactation (on average 2.9 ± 0.2 lactations). Both group received (Table 1) total mixed ration (TMR) balanced according to the requirements of the seventh revised edition of the Nutrient Requirements of Dairy Cattle by the National Research Council (NRC 2001) that meet or exceed the energy needs for a 550 kg lactating Holstein dairy cow producing 35kg/d.

Table 1. Composition of total mixed ration (TMR).

Ingredients of TMR	
Corn silage (%)	30
Grass silage (%)	10
Grass hay (%)	4
Grain concentrate mash (%)	50
Chemical composition of TMR	
Dry matter (DM) (% of diet)	48.8
Neutral detergent fiber (% DM)	28.2
Acid detergent fiber (% DM)	19.8
Non-fiber carbochydrate (% DM)	38.7
Crude protein (% DM)	15.8
Net energy for lactation (Mcal / kg)	1.6

TMR (Table 1) was fed to the cows twice per day at 10:00 am and 08:00 pm. The herd was managed under a zero-grazing system. There was no seasonal pattern of calving during the experimental period.

Body condition scoring was performed by applying a 1-5 point scale according to Olechnowicz and Jaskowski (2014) and classified as follows: emaciated, thin, average, fat, and obese cows. Half and quarter points were used if it required (e.g., 2.5 or 3.25) and the assessor did not have access to the initial scores during the second scoring.

Use of animals

The dairy farmer gave permission for farm data to be used for this study.

Measurements

According to the method of the visual locomotion score (VLS) lameness was recorded on a scale from 1-5 (1 = normal, 2 = presence of a slightly asymmetric gait, 3 = the cow clearly favored 1 or more limbs (moderately lame), 4 = severely lame, to 5 = extremely lame (no weight-bearing lame)) (Bicalho et al. 2007). After evaluation of hoof health status the cows were classified into two groups based on the results gained from VLS: group 1 – "non-lame cows" (VLS of all hoofs were from 1 to 2) and group 2 – cows presenting "lameness" (lame cows) (if at least 1 VLS was ≥3). No cows exhibited other clinical signs associated with mastitis, ketosis or metritis. None of the estrus synchronization protocols was employed in this study.

The cows were milked using a DeLaval AMS (DeLaval International AB, Tumba, Sweden). Milk yield of cows (MY), average milk flow rate (AMFR) and peak milk flow rate (PMFR) were assessed according to the Delaval DelPro 4.2 herd management program. Milking frequency (MF) was measured as the number of milkings per cow per 24 hours. The interval between milkings (MI) was evaluated as the average time (hours) between milkings per day. Milk yield, milking and reproductive traits, and milk progesterone level were compared between cows affected by lameness (lame cows) and healthy ("non-lame") cows. Productivity and milking parameters were assessed from 50 to 100 DIM and 1 day after the first estrus.

The animal was considered to be in estrus when she exhibited one or more of the following: mucous discharge, restlessness and alertness, standing to be mounted, tail raising, congestion of vulval mucous membrane and/or uterine tone. The uterine tone was evaluated by rectal palpation. After 12 h from the beginning of estrus, the cows were inseminated with frozen semen. The pregnancies were tested with "Easi-scan" ultrasound (IMV imaging, Scotland) at 30–35 d post-insemination (once). With the assistance of the herd management program, the interval between calving and first estrus (days), interval from calving to conception (days), and the number of services per pregnancy were registered.

Milk samples for progesterone and milk composition were taken twice, at the beginning of estrus and after 12 hours. Progesterone value was determined using the HORMONOST MILK set produced by the BIOLAB GmbH Company (Munich). Ninety-two milk samples out of the 46 dairy cows (23 lame cows and 23 "non-lame" cows) of second lactation were tested for progesterone level. Cows were inseminated within 12 hours from the appearance of the first signs of estrus.

Statistical analysis

Prior to analyses, all data were screened for normality by assessing the distribution of data using the SPSS statistical package 20.0. Normality of data was tested using the one-sample Kolmogorov–Smirnov test. Data were analyzed by one-way analysis of variance, and dif-

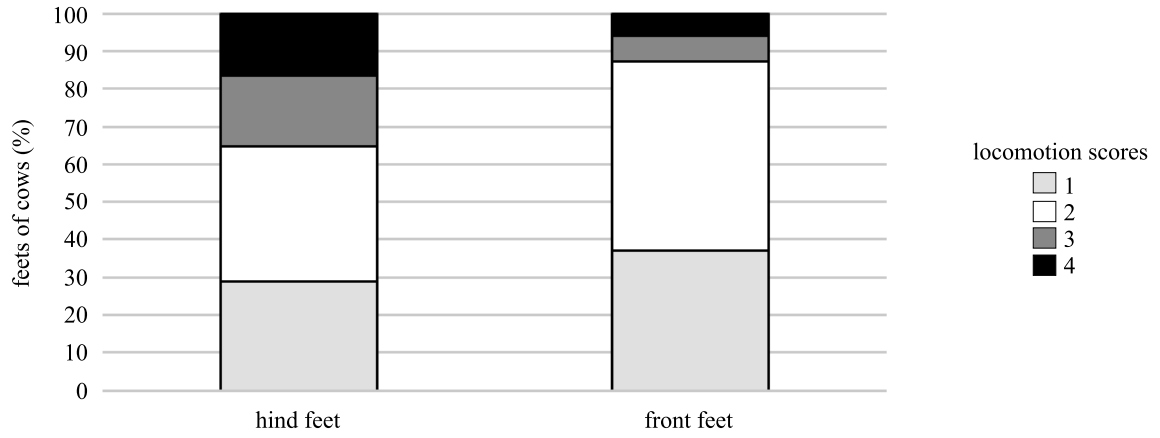

Fig. 1. Prevalence of lameness in dairy cows.

Table 2. Productivity and milkings (mean ± SEM) in lame and non-lame dairy cows.

Group	MY	MF	MI
1 (n=310)	28.03 ± 0.29[a]	2.87±0.01[a]	8.35±0.36[a]
2 (n=108)	26.89±0.33[b]	2.72±0.01[b]	8.83±0.49[b]

[ab] Column means with different superscripts differ significantly at $p<0.05$, MY – milk yield (kg); MF – milking frequency, MI – interval between milkings (h), group 1 – non-lame cows, group 2 – lame cows

ferences between group means were evaluated using the Duncan test. Differences between groups were evaluated with independent t test ($p<0.05$). Pearson's $\chi 2$ test was used to determine whether there was a statistically significant relationship between categorical variables.

Results

Prevalence of lameness and relationship to productivity and milking traits in dairy cows

The average VLS of cows was 2.03±0.01, and milk yield was 27.74±1.06 kg. The percentages of cows with locomotion scores of 1, 2, 3 and 4 were 32.3%, 41.9%, 16.5%, and 9.3%, respectively. The prevalence of lameness (3 or 4 points) was estimated at 25.8%. Likewise, we observed that lameness was mainly localized on the hind feet (79.60%) and less frequently on the front feet (20.40%; $\chi 2=583.818$, df=1, $p<0.001$) (Fig.1).

The cows of group 1 during the period from 50 to 100 DIM were more (4.24% milk per day, $p<0.05$) productive (Table 2). The difference between productivity of rear and front quarters of the udder was lower in "non-lame" cows compared with lame cows group. We estimated that the milk yield from the front quarters accounted on average for 44.1% in group 1 and 42.9% in group 2 ($p<0.05$).

The study revealed that average AMFR was from 5.49% (in front quarters) to 8% (in rear quarters) higher in "non-lame" cows, with PMFR from 5.93% (in front quarters) to 7.69% (in rear quarters) ($p<0.05$) higher compared with lame cows (Fig. 2).

Table 2 shows a significant ($p<0.05$) increment of 5.53% in MI and decrement of 5.19% in MF in lame cows compared to "non-lame" cows.

Relationship between lameness, milking characteristics and some reproductive performance indicators in dairy cows

We found an average 9.41% (from 30.61±1.53 kg to 27.73±1.66 kg) reduction in milk yield of cows one day after start of the first estrus and a 8.58% and 11.99% decline in "non-lame" and lame cows ($p<0.05$), respectively (Fig.3). Significant decrement (26.50%, $p<0.05$) of MF was observed (from 3.40±0.13 to 2.50±0.12 times per day) in group 2. The reduction of MF was from 3.5±0.14 to 2.6±0.12 times (25.71%, $p<0.05$) and from 3.1±0.13 to 2.2±0.10 times per day (29.03%, $p<0.05$) in group 1 and group 2 ($p<0.05$), respectively. Consequently, this reflects ($p<0.05$) increments of MI in "non-lame" (34.62%, from 6.86±0.28 to 9.23±0.42 h) and in lame (40.91%, from 7.74±0.33 to 10.91±0.51 h) cows.

Reproductive traits of cows (Table 3) were statistically different in both groups and affected by lameness ($p<0.05$). The study indicated that the interval from calving to the first estrus was 16.76% shorter in group 1 compared to group 2 ($p<0.05$).

A statistically significant (21.88%; $p<0.05$) increase in the interval from calving to conception was found in group 2.

The results indicate that occurrence of lameness leads to an increased number of inseminations (11.69%;

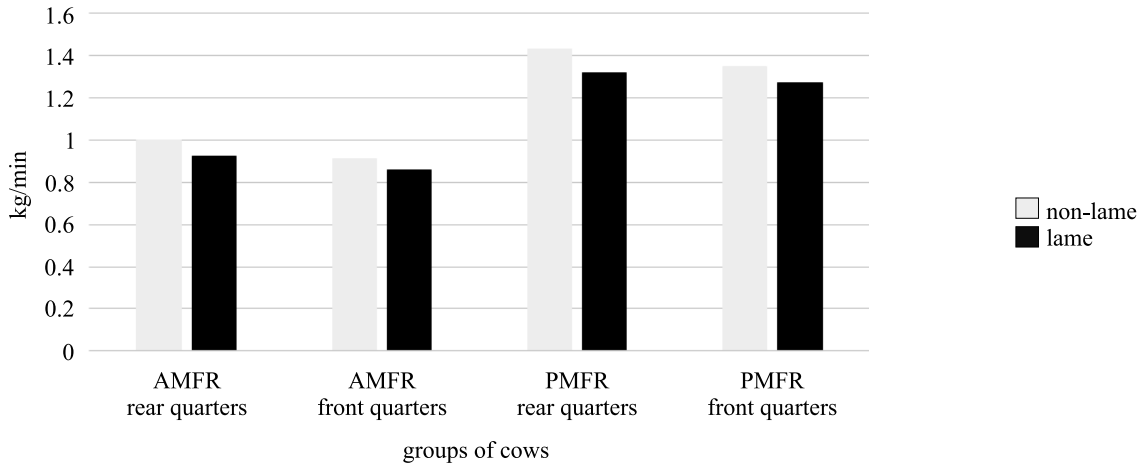

Fig. 2. Milk flow traits in dairy cows.
AMFR – average milk flow rate (kg/min), PMFR – peak milk flow rate (kg/min)

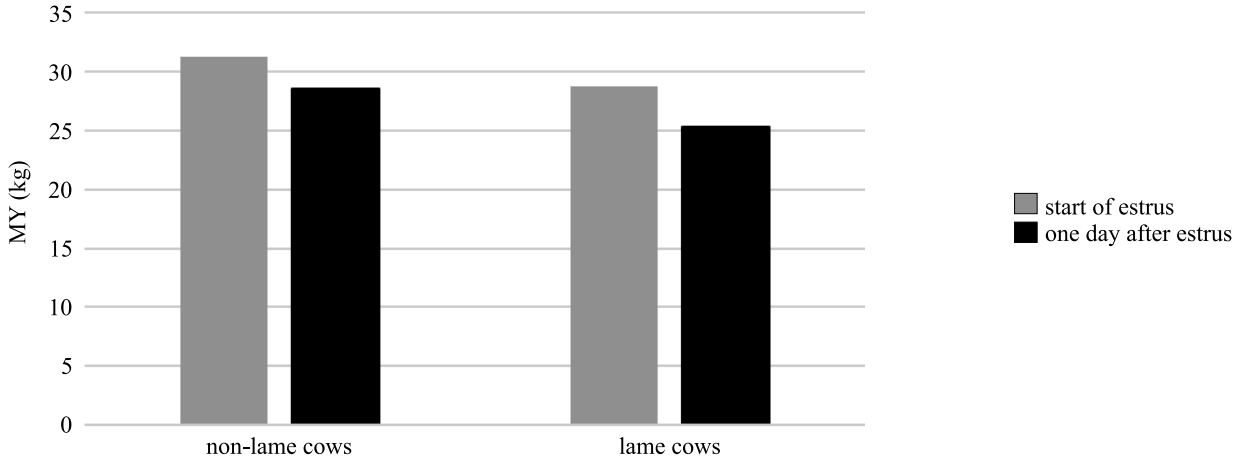

Fig. 3. Changes in productivity of lame and non-lame cows during and after estrus.
MY – milk yield

Table 3. Fertility traits (mean ± SEM) of lame and non-lame cows.

Group	Interval between calving and first estrus (d)	Calving to conception interval (d)	Number of services per pregnancy
1	80.3±3.09[a]	101.9±4.89[a]	1.54±0.05[a]
2	93.7±5.01[b]	124.2±6.3[b]	1.72±0.08[b]

[ab] Column means of groups with different superscripts differ significantly at $p<0.001$, group 1 – non-lame cows

$p<0.05$) and consequently broadens the interval between calvings of dairy cows.

Furthermore, the lame cows exhibited a lower pregnancy rate ($\chi 2=13.466$, df=1, $p=0.001$) (Fig. 4).

Analysis of milk progesterone concentration indicated that progesterone values in lame cows were 1.55-1.76 time's higher at the start of estrus and 12 hours after the start of estrus ($p<0.001$) (Table 4).

Discussion

Foot health has been classified as the most significant welfare problem in dairy cows, and its surveillance is the most representative animal-based indicator of welfare in dairy cattle (Whay et al. 2003, EFSA 2009).

According to the findings of VLS, 25.8% of cows (with VLC evaluation 3 and 4) suffered from lameness. The prevalence of lameness in the present study remains within the range found in other countries, such as the USA, Sweden, Norway, and Thailand (Smilie et al. 1996, Manske et al. 2002, Sogstad et al. 2005, Pilachai et al. 2013).

Milk production, expressed per cow was negatively associated with prevalence of lameness ($p<0.05$). This agrees with previous studies, which have indicated that cows with higher locomotion scores (using similar

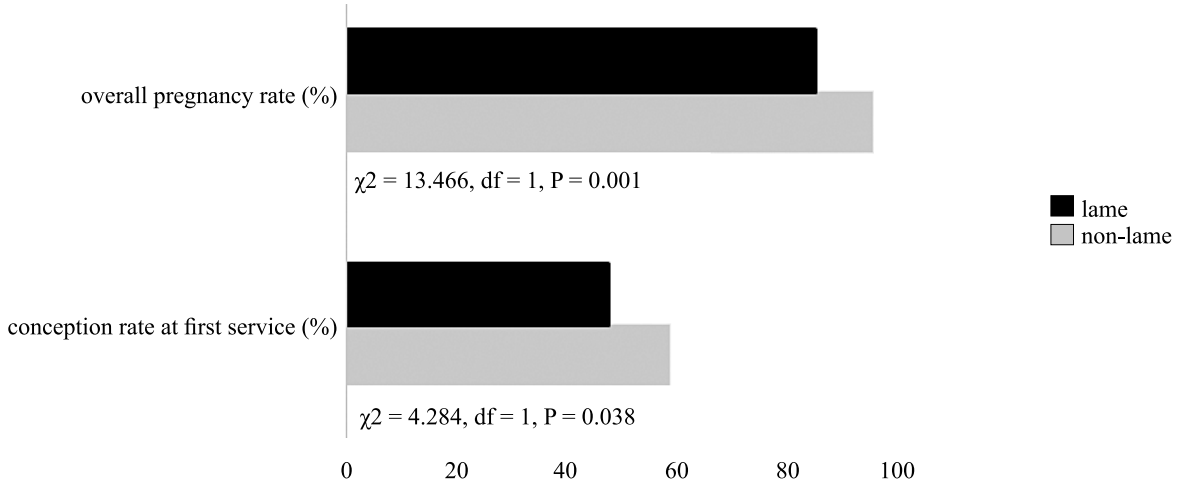

Fig. 4. Relationship between lameness and reproductive performance.
χ2 – Chi-squared test, df – degrees of freedom

Table 4. Progesterone concentration (mean ± SEM) in milk of cows.

Period of estrus	Group of cows	Progesterone concentration (ng/ml)
Start of estrus	Non-lame	2.02±0.13 [a]
	Lame	3.31±0.14 [b]
12 hours after start of estrus	Non-lame	2.78±0.23 [a]
	Lame	4.30±0.20 [b]

[ab] Column means with different superscripts differ significantly at $p<0.05$

5-point scales to ours) produced less milk in fewer total milking's and fewer voluntary milkings (Bach et al. 2007, Deming et al. 2013).

Our results confirm that lameness in Lithuanian Black and White cows was associated with some reproductive performance indicators.

Halli et al. (2015) established that milk yield was slightly reduced (4.1%) 1 day after estrus. We also noted that the decrement in milk yield during estrus can be influenced by lameness score. A more pronounced decline in milk yield was observed in lame cows. This finding could be explained by the fact that predominantly several factors (herd management practices and traits of individual cows) may affect the reproduction of dairy cows (Brand and Guard 1997). However, lameness clearly showed a significant effect on the reproductive traits of lactating cows in this study.

Our data demonstrated that lameness was a consequent predisposing factor for a greater number of services per pregnancy and a greater calving interval. This result is in line with other studies. A study conducted by Sogstad et al. (2006) revealed that lame cows required more reproductive hormonal treatments. Hoof lesions and lameness were associated with increasing calving interval (Hernandez et al. 2002, Machado et al. 2010, Alawneh et al. 2011) and increasing treatment of anestrus (Hultgren et al. 2004). Results of studies by Arunvipas et al. (2011) indicated that lame cows exhibited a lower pregnancy rate (OR = 3.5) than "non-lame" cows.

In our study the lame cows showed a lower pregnancy rate. This finding could be linked to a higher progesterone level during estrus. Based on milk progesterone levels, a greater value of progesterone near the time of insemination was negatively associated with a successful pregnancy (Bruinjéa et al. 2017).

Walker et al (2010) reported that lame cows had lower progesterone values during the 6 days before estrus ($p\leq0.05$). Fewer lame cows were observed in estrus following PG (non-lame 83%, lame 53%; $p=0.030$); however, if prior progesterone concentrations were elevated, lame cows were just as likely to be observed in estrus. In conclusion, following endogenous progesterone exposure, lameness shortens the period when herd-mates attempt to mount lame cows but does not affect the incidence of estrus. However, lame cows are mounted less frequently and express estrus of lower intensity. This is associated with lower progesterone prior to estrus but not with abnormal estradiol or cortisol profiles in daily milk samples.

Gómez et al. (2003) estimated that subclinical hoof disorders have no influence on the intensity of estrus. According to our results, in lame cows with clinical disorders of hoof the level of progesterone concentration in milk was higher ($p<0.001$), but the sample we

studied was not large and studies with a larger number of cows would be needed in the future.

To sum up, we can state that lameness had a tendency to decrease milk production, milk flow traits, and milking frequency in dairy cows. During estrus the lame cows presented a more pronounced decrease in milk yield and milking frequency, a lower pregnancy rate and a higher interval from calving to conception than "non-lame" cows.

Overall, our results indicate that lameness influenced the visiting frequency of AMS, the interval between milking and the productivity of the cows. The convergence of all the consequences have a negative impact on herd profitability, and the health and welfare status of the cows. It is highly recommended that comprehensive analysis of AMS variables should be performed in order to guarantee effective management of reproductive performance and hoof health of dairy cows.

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