ORIGINAL ARTICLE

Milkability evaluation of Holstein dairy cows by Lactocorder

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Abstract

The aim of this work was to evaluate chosen milk flow characteristics of Holstein dairy cows, using mobile electronic milk flow meters – Lactocorders. A total of 181 Holstein dairy cows were evaluated and divided according to parity, lactation stage and bimodality in order to carry out a detailed comparison of measured milkability traits. The average total milk yield was 11.98 ± 3.41 kg per milking with an average milk flow rate of 2.52 ± 0.75 kg min⁻¹ and a maximum milk flow rate of 3.94 ± 1.30 kg min⁻¹. The total milk yield showed positive correlations with the average milk flow rate ($r = 0.48$; $P < 0.001$) and also with the maximum milk flow rate ($r = 0.32$; $P < 0.001$). More than 47% of milk flow curves were classified as bimodal. Bimodality was positively correlated with the duration of the incline phase ($r = 0.73$; $P < 0.001$) and negatively correlated with the quantity of milk obtained during the first minute of milking ($r = -0.34$; $P < 0.001$). In relation to the lactation stage – the highest average milk flow rate was reached by Holstein dairy cows at the beginning of the lactation (up to 100 days in milk), and in relation to parity – the highest milk flow rates were measured in second-lactation dairy cows.

Key words: milkability; lactocorder; Holstein breed; bimodality

INTRODUCTION

Dairy farmers place considerable emphasis on milkability, because slow milking cows hinder the milking process of the herd, especially in milking

parlours (Krogmeier et al. 2006). In addition to the economic aspects of milk production and monitoring of milking efficiency for farmers, the recording of milk flow is used for the evaluation and development of milking machines and in setting parameters for their use (Thomas et al. 1991, Rasmussen 1993). The evaluation of milk flow traits is also important in connection with establishing the efficiency of milk ejection (Tančin and Bruckmaier 2001). Moreover recent studies on milk flow traits showed an association with udder health or somatic cell count (Mijic et al. 2005, Tančin et al. 2007). The effect of the lactation stage on milk flow traits was analysed

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by Sandrucci et al. (2007), who noted significantly a higher average milk flow rate in Holstein dairy cows in the first half of lactation (up to 150 days in milk). The parity effect on milkability traits was analysed by Dudenhoff et al. (1999) who detected that primiparous cows achieved lower milk flow rates in comparison with multiparous cows. On the other hand the highest occurrence of bimodality was measured in second-lactation dairy cows.

The objectives of this research were to evaluate the milk flow traits of Holstein dairy cows by Lactocorders and to make a comparison of these traits among Holstein dairy cows divided according to parity, lactation stage and bimodality. We also wanted to find correlations between the chosen traits and the parameters of milkability and to detect significant differences between the compared groups of cows.

MATERIALS AND METHODS

All of our measurements by Lactocorder were carried out in 3 farms specializing in the Holstein breed, where the cows were milked three times a day and which were located in western Slovakia. The average lactation milk yield of the farms ranged from 9000 to 10 000 kg year⁻¹. Measuring was accomplished during one week and performed by two electronic mobile milk flow meters – Lactocorders – which were installed between the milking equipment and the milking tube before each milking. We evaluated a total of 181 Holstein dairy cows which were consequently divided according to parity, lactation stage and bimodality:

1. Parity: Cows in the first lactation (n = 67), Cows in the second lactation (n = 63), Cows in the third and greater lactations (n = 51).
2. Lactation stage: Up to 100 days in milk (L₁; n = 40), From 100 to 200 days in milk (L₂; n = 55), More than 200 days in milk (L₃; n = 86).
3. Bimodality: With bimodality (n = 86), Without bimodality (n = 95).

The Lactocorder evaluates only the so called main phase of milking, which begins after exceeding a milk flow of 0.5 kg min⁻¹ and ends when the milk flow drops below 0.2 kg min⁻¹. The milk flow rate was electronically recorded every 0.7 s and the data detected were saved at intervals of 2.8 s. The samples for the somatic cell count were automatically collected by Lactocorder during each measuring and then sent for analysis to a certified laboratory in Žilina (The breeding

service of the Slovak republic). The somatic cell count values were converted to a somatic cell score (SCS) by the following equation: $LS = \log_2 (\text{Somatic cell count}/100) + 3$ (Wiggans and Shook 1987).

In our study, the following parameters were measured and evaluated: *total milk yield* (kg) (The milk yield from the beginning to the end of the measurement); *maximum milk flow rate* (kg min⁻¹) (Maximum milk flow in the main milking process within a time interval of 22.4 seconds /8 measuring points/); *average milk flow rate* (kg min⁻¹) (Average main milking process per minute kg min⁻¹); *duration of main phase* (min) (time of main milking process by machine: beginning of the milk flow = 0.50 kg min⁻¹ until a milk flow of 0.20 kg min⁻¹ at the decline is reached); *duration of incline phase* (min) (Timely part of the main milking process from the milk flow of 0.50 kg min⁻¹ to the top of the plateau phase); *duration of plateau phase* (min) (Time from the top of the incline to the top of the decline); *duration of decline phase* (min) (Time from the top of decline until the milk flow falls below 0.20 kg min⁻¹); *bimodality* (%) (Steep decrease of milk flow in time up to 96 seconds after the beginning of milking); *dual peak milk flow curve* (The quantity of milk obtained during the first minute of milking (kg) – milk yield from the beginning of the measurement to the end of the first measuring minute).

The results of our measurements were processed by the software program pack “LactoPro 5.2.0” (Biometeltechnik Swiss). We used SAS 9.1 for analysis and data calculation. Pearson correlation analyses were performed by using the CORR procedure (SAS 9.1). Parity and lactation stage data were analysed by one-way analysis of variance (ANOVA – Scheffe’s test). We used the t-test in order to detect significant differences between compared “Bimodality groups” of Holstein dairy cows. The aim was also to find out which of the chosen effects most influenced the average milk flow rate, as the general milkability trait. We used the following linear model, where the average milk flow rate was dependent variable:

$$Y_{ijklm} = \mu + PAR_i + FARM_j + MGG_k + DIM_l + {}_tMHG_m + e_{ijklmn}$$

Y_{ijklm} = average milk flow rate (Dependent Variable); μ = mean; PAR_i = parity i (i = 1–7); $FARM_j$ = herd j (j = 1–3); MGG_k = linear regression of total milk yield k; DIM_l = stage of lactation l (1–3); ${}_tMHG_m$ = linear regression of duration of the main phase of milking m; e_{ijklmn} = random residual effect n

RESULT AND DISCUSSION

In the group of Holstein dairy cows evaluated ($n = 181$), we detected an average total milk yield of 11.98 ± 3.41 kg per milking, with an average milk flow rate of 2.52 ± 0.75 kg min⁻¹ and a maximum milk flow rate of 3.94 ± 1.30 kg min⁻¹. Lower values of these milkability parameters were reported by Lee and Choudhary (2006), who measured in Holstein dairy cows an average milk flow rate of 2.30 kg min⁻¹ and a maximum milk flow rate of 3.21 kg min⁻¹. On the other hand, higher mean values of maximum (4.49 kg.min⁻¹) and average (2.84 kg min⁻¹) milk flow rates were reported by Strapák et al. (2009), who also evaluated milk flow traits of Holstein dairy cows by Lactocorder. In our study, the total milk yield revealed a positive correlation with average ($r = 0.48$; $P < 0.001$) and maximum ($r = 0.32$; $P < 0.001$) milk flow rates. This is in accordance with Juozaitiene and Jaspertiene (2010) who also estimated significant positive correlations between total milk yield and milkability traits. Sandrucci et al. (2007) detected a positive relation between milk yield per milking and maximum milk flow rate

($r = 0.33$; $P < 0.001$). In our research 47.51% of milk flow curves were classified as bimodal. According to Tančin and Bruckmaier (2001) the high percentage of bimodal milk flow curves indicates that the cows were not well prepared for machine milking. A lower percentage of bimodal milk flow curves was observed by Tamburini et al. (2010) and Sandrucci et al. (2007).

Parity

In a further part of our study we divided Holstein dairy cows according to parity. The highest total milk yield, average and maximum milk flow rates were reached by dairy cows in the second lactation. On the other hand, the lowest values of the traits mentioned were measured in primiparous dairy cows (Table 1). This is in accordance with Dodenhoff et al. (1999), who also evaluated the milk flow traits of Holstein dairy cows divided according to parity, and also detected the lowest total milk yield, average and maximum milk flow rates in primiparous cows. Similar results have been published by Tančin et al. (2005), who found lower average and maximum milk flow rates in primiparous cows, compared with older cows.

Table 1. Milk flow parameters and traits of milking of Holstein dairy cows divided according to parity (mean $\pm$ standard deviation)

Trait	Parity			Significance
	1.	2.	3. and <	
Number of cows (n)	67	63	51	
Total milk yield (kg)	11.48 $\pm$ 2.27	12.54 $\pm$ 3.81	11.94 $\pm$ 4.05	ns
Average milk flow rate (kg min ⁻¹)	2.44 $\pm$ 0.74	2.67 $\pm$ 0.75	2.45 $\pm$ 0.74	ns
Maximum milk flow rate (kg min ⁻¹)	3.67 $\pm$ 1.31	4.22 $\pm$ 1.28	3.96 $\pm$ 1.24	ns
Bimodality (%)	38.81	57.14	47.06	ns
Duration of main phase (min.)	4.96 $\pm$ 1.69	4.66 $\pm$ 1.27	4.94 $\pm$ 1.66	ns
Duration of incline phase (min.)	0.88 $\pm$ 0.48	1.04 $\pm$ 0.41	1.05 $\pm$ 0.49	ns
Duration of plateau phase (min.)	2.21 $\pm$ 1.52	1.53 $\pm$ 1.10	1.70 $\pm$ 1.61	1–2*
Duration of decline phase (min.)	1.87 $\pm$ 1.03	2.08 $\pm$ 0.73	2.20 $\pm$ 1.16	ns
The quantity of milk obtained during first minute of milking (kg)	2.10 $\pm$ 1.03	2.42 $\pm$ 1.07	2.51 $\pm$ 1.19	ns
SCS	2.07 $\pm$ 1.70	2.35 $\pm$ 2.11	3.07 $\pm$ 2.16	1–3*

ns = non-significant; * $P < 0.05$

We observed the highest occurrence of bimodality in the group of cows in the second lactation (57.14%). Dodenhoff et. al (1999) also detected the highest percentage of bimodal milk flow curves in second-lactation cows, but it is necessary to underline that his values of

bimodality were generally more than half lower (24%). A similar level of bimodality was measured by Strapák et al. (2009). In their study, bimodality ranged from 50–56%, depending on parity. The difference between the optimal and bimodal milk flow curve is shown in Figs 1 and 2.

Fig. 1. Milk flow curve without bimodality

Fig. 2. Milk flow curve with bimodality

Our research also included somatic cell score evaluation. The aim was to explore the relationship between the somatic cell score and milkability traits, but no significant correlations were detected. The highest somatic cell score (3.07 ± 2.16) was measured in the group of Holstein dairy cows in the third and higher lactations; on the other hand, the lowest value was reached by primiparous dairy cows (2.07 ± 1.70). This tendency was confirmed by Antalík and Strapák (2010, 2011) who also observed that primiparous cows have a lower somatic cell count in comparison to multiparous cows.

We found significant differences ($P < 0.05$) between primiparous cows and second-lactation cows in traits of the plateau phase and between primiparous cows and third/greater lactation-cows in traits of the somatic cell score.

Lactation stage

In our study, three of the parameters evaluated were significantly ($P < 0.001$) influenced by the lactation stage. Significant negative correlations were found between days in milk and total milk yield ($r = -0.52$; $P < 0.001$), main phase ($r = -0.34$; $P < 0.001$) and plateau phase of milking ($r = -0.35$; $P < 0.001$). The highest total milk yield, average

and maximum milk flow rates were detected in the group of cows “up to 100 days in milk”. On the other hand, the lowest values of the traits mentioned were observed in the group of cows “more than 200 days in milk” as we expected. This group of Holstein dairy cows reached also the highest percentage of bimodal milk flow curves (56.98%) (Table 2). This is in accordance with Antalík and Strapák (2011) who detected in Slovak Simmental dairy cows – divided according to lactation stage – the lowest values of total milk yield and average milk flow rate in the group of cows “more than 200 days in milk” (7.8 kg and 1.60 kg min^{-1} respectively). Contrary to our results, the highest values of milk flow rates were not found in cows at the beginning of lactation, but in the group of dairy cows “from 100 to 200 days in milk” (2.22 kg min^{-1} and 3.09 kg min^{-1}). Sandrucci et al. (2007) who measured milk flow parameters in Holstein-Friesian dairy cows also detected the lower values of average and maximum milk flow rates in dairy cows in the second half of lactation (2.36 kg min^{-1} and 3.75 kg min^{-1}), and also detected in the group of Holstein-Friesian dairy cows the highest occurrence of bimodality (40.60%).

Table 2. Milk flow parameters and traits of milking of Holstien dairy cows divided according to lactation stage (mean $\pm$ standard deviation)

Trait	Lactation stage			Significance
	L ₁	L ₂	L ₃	
Number of cows (n)	40	55	86	
Total milk yield (kg)	13.84 ± 3.52	13.57 ± 2.62	10.10 ± 2.79	L ₁ –L ₃ *; L ₂ –L ₃ *
Average milk flow rate (kg min^{-1})	2.80 ± 0.95	2.58 ± 0.63	2.36 ± 0.67	L ₁ –L ₃ *
Maximum milk flow rate (kg min^{-1})	4.21 ± 1.55	3.89 ± 1.22	3.85 ± 1.21	ns
Bimodality (%)	40	38.18	56.98	ns
Duration of main phase (min.)	5.23 ± 1.75	5.38 ± 1.39	4.34 ± 1.39	L ₁ –L ₃ *; L ₂ –L ₃ *
Duration of incline phase (min.)	0.95 ± 0.47	0.92 ± 0.36	1.05 ± 0.51	ns
Duration of plateau phase (min.)	2.23 ± 1.47	2.28 ± 1.42	1.35 ± 1.30	L ₁ –L ₃ *; L ₂ –L ₃ *
Duration of decline phase (min.)	2.05 ± 0.90	2.18 ± 1.03	1.94 ± 0.98	ns
The quantity of milk obtained during first minute of milking (kg)	2.57 ± 1.19	2.52 ± 1.00	2.09 ± 1.07	ns
SCS	1.99 ± 1.96	2.41 ± 2.10	2.69 ± 1.85	ns

Comparisons significant at the 0.05 level are indicated by *

L₁ – Up to 100 Days in milk; L₂ – From 100 to 200 Days in milk; L₃ – More than 200 Days in milk

ns = non-significant

We detected that the traits of total milk yield, average milk flow rate, and the duration of the main and the plateau phase of milking were significantly ($P<0.05$) different between dairy cows “up to 100 days in milk” and “more than 200 days in milk”. Between dairy cows “from 100 to 200 days in milk” and “more than 200 days in milk” we found significant differences ($P<0.05$) in traits of bimodality, total milk yield, and the main and plateau phase of milking. No significant differences were found in traits evaluated between groups of cows “up to 100 days in milk” and “from 100 to 200 days in milk”.

Bimodality

In the last part of our research we divided Holstein dairy cows according to bimodality. We detected a higher total milk yield (12.34 ± 3.42 kg) and average milk flow rate (2.56 ± 0.81 kg min⁻¹) in the group of cows without bimodality. The cows with bimodality reached a more than twice longer incline phase of milking and a markedly lower quantity of milk obtained during

the first minute of milking (Table 3). As we mentioned before, bimodality is connected with the beginning of the milking process – so the interruption of milk flow typical for bimodality, leads to a prolongation of the incline phase and also to a decrease in the quantity of milk obtained during first minute of milking. These relations were confirmed in a correlation analysis, which showed a positive significant correlation between the bimodality and the incline phases ($r = 0.73$; $P<0.001$) and a significant negative correlation between bimodality and the quantity of milk obtained during first minute of milking ($r = -0.35$; $P<0.001$). The cows with bimodal milk flow curves also reached a higher somatic cell score (2.62 ± 2.12). We found no significant correlation between bimodality and the somatic cell score. Using the t-test, it was detected that the traits of quantity of milk obtained during first minute of milking, and the main and plateau phase of milking were significantly ($P<0.001$) different between Holstein dairy cows “with” and “without” bimodality (Table 3).

Table 3. Milk flow parameters and traits of milking of Holstein dairy cows divided according to bimodality (mean $\pm$ standard deviation)

Trait	Bimodality		
	Without bimodality	With bimodality	Significance (t-test)
Number of cows (n)	95	86	
Total milk yield (kg)	12.34 ± 3.42	11.58 ± 3.38	0.138
Average milk flow rate (kg min ⁻¹)	2.56 ± 0.81	2.49 ± 0.67	0.549
Maximum milk flow rate (kg min ⁻¹)	3.74 ± 1.27	4.17 ± 1.29	0.023
Duration of main phase (min.)	5.02 ± 1.74	4.67 ± 1.29	0.119
Duration of incline phase (min.)	0.66 ± 0.32	1.34 ± 0.32	<0.001
Duration of plateau phase (min.)	2.27 ± 1.52	1.34 ± 1.18	<0.001
Duration of decline phase (min.)	2.09 ± 1.05	1.98 ± 0.89	0.460
The quantity of milk obtained during first minute of milking (kg)	2.69 ± 1.06	1.92 ± 1.00	<0.001
SCS	2.29 ± 1.91	2.62 ± 2.12	0.098

Table 4. Linear model with dependent variable of average milk flow rate

Effect	F-Value	Significance
Parity	15.83	<0.001
Farm	4.38	<0.05
Total milk yield	302.24	<0.001
Lactation stage	12.14	<0.01
Duration of main phase of milking	926.92	<0.001

R² of linear model = 0.88

Linear model

According to the linear model with a dependent variable, we detected that the average milk flow rate, which is considered a general milkability trait, was most influenced by the duration of the main phase of milking, the total milk yield and parity (in all mentioned parameters at the significant level of $P < 0.001$). The average milk flow rate was also significantly influenced by the lactation stage ($P < 0.01$) and by farm ($P < 0.05$) (Table 4).

The results of our study show that the average milk flow rate was most influenced by the duration of the main phase of milking and by the total milk yield. Correlation analyses confirmed that there is a significant relationship between total milk yield and average and maximum milk flow rates. With regard to parity, the highest average and maximum milk flow rates were detected in the group of cows in the second lactation, and with regard to the lactation stage, the highest average and maximum milk flow rates were measured in the group of cows “up to 100 days in milk”. For official milk-recording and milkability evaluations in Slovakia, the milkmeter (Tru-Test) is used, and the milk flow rate measurement is based on the total milk yield and milking time – which is detected by stop-watch. The Lactocorder provides many more milkability parameters and traits of milking and this could be a big advantage for the farmer, because more information about cows means more possibilities for herd management. For example bimodality can be used as an indicator of non-optimal udder prestimulation before milking. When there is a high percentage of bimodal milk flow curves in the herd, it is a signal for the farmer that something is wrong with the pre-milking operations.

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