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Milkability differences based on lactation peak and parity in Holstein cattle

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ABSTRACT. The aim of this study was to evaluate differences in milkability based on lactation peak and parity in Holstein cattle. Milk yield, actual milking time, milking time differences, occurrence of bimodal milk flow, average and partial milk flows within the first two minutes of milking were monitored for each milking during the first 120 days in milk (DIM). The Holstein cows (n = 135) were divided into groups according to the day when they achieved lactation peak (lactation peak group (LPG): 0–30 DIM; 30–60 DIM; 60–90 DIM and 90–120 DIM) and parity (primiparous and multiparous cows). The obtained results suggested that the values of milk yield were higher when cows reached the lactation peak between 30–60 DIM regardless of parity (15.62 and 19.65 kg for primiparous and multiparous cows, respectively). The shortest milking times were achieved by both primiparous (7:03 min) and multiparous (7:39 min) cows in LPG90–120. The average milk flow per min was higher in LPG30–60 and LPG90–120 for both parity groups. Primiparous cows in LPG30–60 and LPG60–90 had a lower incidence of bimodal milk flows, while multiparous cows had the highest proportion of bimodal flows in LPG90–120. High values of partial milk flows during the first 15 s of milking were achieved by primiparous cows in LPG30–60, LPG60–90 and LPG90–120, while multiparous cows had the highest values for LPG90–120. Other partial milk flows from 15 s to 2 min of milking showed a similar trend of higher values in LPG30–60 and LPG90–120 regardless of parity, except partial flow from 30 to 60 s for primiparous cow. The results showed that there is no one ideal LPG for all milkability parameters. In terms of milk yield, lactation peak is optimal between 30–60 DIM. Therefore, such animals should be considered for breeding and targeted for milking efficiency.

Introduction

A proper modern milking practice requires fast and effective milk release while maintaining good hygienic conditions. It is important to ensure a good quality environment for the required milk yield and quality of milk with regard to the welfare of dairy cows (Bruckmaier and Hilger, 2001).

The breeding objective in recent years was to improve selected milkability parameters (Govignon-Gion et al., 2016). Yamazaky et al. (2011) and Satoła and Ptak (2019) stated that the milkability parameters include, for example, initiation of milking and milk flow, lactation peak, and milking speed traits that have a negative correlation with the total milking time during the main milking phase (Lee and Choudhary, 2006; Tančin et al., 2006). Sandrucci et al. (2007) added that higher milk flow during the first half of lactation is more important in primiparous Holstein cows than in multiparous cows. The primiparous cows produce less milk at the beginning of lactation and at the lactation peak (Atashi and Asaadi, 2019), which is related to the lower milk yield at lactation peak (Tekerli et al., 2000). They also had higher persistency of lactation compared to multiparous, as confirmed by Yamazaki et al. (2011), who further stated that cows with a later lactation peak have a higher persistency of lactation but a lower milk yield. This also has a positive effect on udder health. However, Pollott (2011) added that the day of lactation peak shifts with the parity, and the faster onset of the lactation peak the lower persistency of lactation. In the study of Steri et al. (2012), lactation peak was mostly achieved between 40 and 65 day in milk (DIM), in which the milk production was up to 38 kg. The study of Torshizi (2016) also found a positive correlation between lactation peak time and average milk yield. In that study, milk flow curves described milk release and flow rates. Milk flow curves are affected by parity, DIM, maximum milk flow, and most importantly, by pre-milking operations (Sandrucci et al., 2007). Bobić et al. (2020) state that dairy cows with a bimodal milk flow curve had significantly lower average milk flow and longer descending phase of the milk flow curve.

Based on the literature overview, milkability parameters are important for breeding and may be influenced by various effects. It is generally known that dairy cows achieve lactation peaks around 60 DIM. On the other hand, most cows reach their lactation peak outside 60 DIM. Possible differences among lactation peak groups, or furthermore among parity groups, might provide useful information on the milkability behaviour of early-and late-peaking cows.

The study aimed to compare milkability parameters of monitored cows based on the interaction between parity and the period in which they reached lactation peak. In addition, this study also aimed to test the effectiveness of milking in early lactation and the viability of peak lactation as a breeding goal.

Material and methods

Ethics statement

This experiment was carried out in accordance with Czech legislation for the protection of the animals against abuse (No. 246/1992) and with directive 2010/63/EU on the protection of animals used for scientific purposes.

Animals and samples

This study was conducted on a commercial dairy farm with Holstein cows in the Central Bohemian Region of the Czech Republic. In total, 135 dairy cows (first lactation n = 51 cows; second lactation n = 34 cows; third lactation n = 30 cows; fourth lactation n = 12 cows; fifth and further lactations n = 8 cows) were monitored. Cows were housed in one free-stall barn, bedded with recycled solid manure. Cows were milked twice a day in the herringbone parlour with 24 places. Stimulation was done by milking first streaks from each teat, followed by udder cleaning and mechanical stimulation. Critical milk flow for the automatic detachment system was set to 0.5 kg/min. Pulsation was set to a 60:40 ratio with 55 pulses per min. The vacuum level was set to 42 kPa.

Data collection

Milkability during the first 120 DIM was monitored for all cows that calved from November 2016 to February 2017. The day of lactation peak was identified for each cow based on the first maximum daily milk yield within the first 120 DIM. Data about average milk yield per milking (MY; kg), actual milking time (AMT; min), average milk flow (AMF; kg/min) and partial milk flows within the first two minutes of milking (milk flow during 0–15 s (MF0–15), milk flow during 15–30 s (MF15–30), milk flow during 30–60 s (MF30–60), milk flow during 60–120 s (MF60–120); kg/min) were obtained from 'inline' and 'real-time' milk analyzers Afilab (Afimilk Ltd., Kibbutz Afikim, Israel) for each milking. Occurrence of bimodal milk flows (BimMF) was detected when two increments of milk flow were followed by a clear drop in milk flow by more than 0.2 kg/min within one minute after the start of milking (Dzidic et al., 2004b). Data for each cow in the test consisted of around 240 individual milking records, obtained during the first 120 DIM. Milking time difference (MTd) was calculated as the difference between actual milking time and pre-calculated milking time (MTd = AMT − AMT target); where AMT target is the pre-calculated target for AMT according to the expected milk yield calculated by the Afifarm system (Afimilk Ltd., Kibbutz Afikim, Israel). The MTd represented the difference in the expected milking time.

Statistical analysis

Statistical evaluation was performed by the SAS software ver. 9.4 (SAS/STAT®; SAS Institute Inc., Carry, NC, USA). Basic statistics were calculated by the UNIVARIATE procedure. Correlation analysis was done by the CORR procedure. The STEPWISE method and the REG procedure were used to select suitable effects for the model equation. The MIXED procedure was used for the main evaluation. The model equation consisted of fixed effect of milking time, lactation peak group (LPG), parity, the interaction between LPG and parity, linear regression on DIM and the date of milking, and random repeated effect of the cow. For the main evaluation, cows were divided into primiparous and multiparous. Cows were furthermore divided into 4 groups based on the day in which they reached lactation peak (1–30 DIM = LPG0–30; 31–60 DIM = LPG30–60; 61–90 DIM = LPG60–90; 91–120 DIM = LPG90–120). Differences of least squares means were calculated using the Tukey-Kramer test. The following model equation was used:

$$y_{ijkl} = \mu + TM_i + LPG_j + PARITY_k + (LPG \times PARITY)_{jk} + b_1{*}(DIM) + b_2{*}(DATE) + cow_l + e_{ijkl};$$

where: y_{ijkl} – measured value of dependent variables (MY, AMT, MTd, AMF, BimMF, MF15–30, MF30–60, MF60–120); μ – mean value of the dependent variable; TM_i – fixed effect of milking time (sequence) (i = morning, n = 16 167; i = evening, n = 16 225); LPG_j – fixed effect of lactation peak group (j < 30 day, n = 2400; j = 30–60 day, n = 13 673; j = 60–90 day, n = 8880; j > 90 day, n = 7439); $PARITY_k$ – fixed effect of parity (k = 1, n = 12 239; $k \geq 2$, n = 20 153); $(LPG\times PARITY)_{jk}$ – interaction between effects of lactation peak group and lactation parity; b_1*(DIM) – linear regression on days in milk; b_2*(DATE) – linear regression of the date of measurement; cow_l – random effect of the cow (l = 135); e_{ijkl} – random residual error.

Significance levels $P < 0.05$ (*) and $P < 0.01$ (**) were used to evaluate the differences between groups.

Results

Basic statistics for monitored milkability parameters of tested cows are presented in Table 1. The table shows the numbers of observations, arithmetic means, minimum and maximum. Further, the table shows the values of the standard deviation or coefficient of variation.

Table 1. Basic statistics for monitored milkability parameters of tested cows

Indices	N	Means	SD	Minimum	Maximum	CV
MY, kg	32 392	17.44	4.27	0.20	37.60	24.47
AMT, min	32 392	7:52	2:18	1:12	26:48	29.28
MTd, min	31 667	1:45	2:18	−5:30	21:06	131.24
AMF, kg/min	32 392	2.35	0.72	0.07	5.33	30.76
BimMF, %	30 470	0.21	0.41	0.00	1.00	194.94
MF0–15, kg/min	32 392	0.31	0.49	0.00	4.40	160.67
MF15–30, kg/min	32 392	2.36	1.16	0.00	8.26	49.44
MF30–60, kg/min	32 392	2.74	1.08	0.00	8.29	39.36
MF60–120, kg/min	32 392	3.08	1.13	0.00	8.68	36.70

MY – milk yield (kg); AMT – actual milking time (min); MTd – milking time difference (min); AMF – average milk flow (kg/min); BimMF – bimodal milk flow (%); MF0–15 – milk flow between first 0–15 s of milking (kg/min); MF15–30 – milk flow between 15–30 s of milking (kg/min); MF30–60 – milk flow between 30–60 s of milking (kg/min); MF60–120 – milk flow between 60–120 s of milking (kg/min); N – number of observations; SD – standard deviation; CV – coefficient of variation (%)

Next, a correlation analysis of monitored parameters was performed (Table 2). Relation between MY and AMT was notable for all LPGs, which was also confirmed by the correlation analysis (primiparous cows r = 0.140, $P < 0.01$; multiparous cows r = 0.323, $P < 0.01$). The results also suggested a strong positive correlation between AMT and MTd (primiparous cows r = 0.977, $P < 0.01$; multiparous cows r = 0.945, $P < 0.01$). As expected, AMT and AMF (primiparous cows r = −0.728, $P < 0.01$; multiparous cows r = −0.630, $P < 0.01$) were negatively correlated. Correlation analysis also showed a strong positive correlation between AMF and all partial milk flows.

The model equation was statistically significant ($P < 0.01$) for all monitored parameters. All effects on AMT, AMF, MF15–30, MF30–60 and MF60–120 were statistically significant ($P < 0.01$). The exceptions in this were: the DIM effect on MY, milking time effect on MTd, and the effect of DIM, date on the BimMF, cow on MF0–15 as the dependent variable, which was not statistically significant.

The higher MY ($P_{PARITY} < 0.01$; Table 3) was observed for multiparous cows compared to primiparous cows, which applies to all LPGs. The highest MY was observed for multiparous cows in LPG30–60 (19.65 kg; $P < 0.01$). The longer AMT for relatively low MY for multiparous cows in LPG0–30 was noticed, and this group achieved the longest AMT (8:29 min; $P < 0.01$) among all LPGs regardless of parity. The lowest value of AMT (7:03 min) was measured for primiparous cows in LPG90–120. The highest MTd values were observed for primiparous cows in LPG0–30, LPG30–60 and for multiparous one in LPG0–30. The milking was prolonged in these groups by an average by 2:10, 2:14 and 2:08 min, respectively ($P < 0.01$). The difference of more than two minutes was observed for primiparous cows in LPG0–30 and LPG30–60, but only in LPG0–30 for multiparous cows. On the other hand, the lowest MTd was stated in LPG90–120 regardless of parity.

Our observed difference in LPG between the highest and lowest AMF value in the primiparous was +0.12 kg/min, while the same difference in multiparous was +0.32 kg/min. The lowest AMF were reached by primiparous cows in LPG0–30 and LPG60–90 (2.04 and 2.03 kg/min, respectively; $P < 0.01$; Table 3), while for multiparous cows the lowest AMF was in LPG0–30 (2.24 kg/min) which was still higher than the highest values for primipa-

Table 2. Correlation analysis between monitored milkability parameters

Monitored parameters	PARITY	AMT	MTd	AMF	BimMF	MF0–15	MF15–30	MF30–60	MF60–120
MY	1	0.140**	0.013^{NS}	0.495**	−0.027*	0.236**	0.381**	0.419**	0.416**
	≥2	0.323**	0.143**	0.460**	−0.018**	0.173**	0.248**	0.269**	0.356**
AMT	1		0.977**	−0.728**	−0.048**	−0.352**	−0.612**	−0.646**	−0.704**
	≥2		0.945**	−0.630**	−0.019*	−0.437**	−0.572**	−0.580**	−0.596**
MTd	1			−0.786**	−0.053**	−0.387**	−0.663**	−0.698**	−0.759**
	≥2			−0.710**	−0.028**	−0.461**	−0.605**	−0.606**	−0.657**
AMF	1				−0.000^{NS}	0.539**	0.794**	0.866**	0.916**
	≥2				−0.009^{NS}	0.606**	0.746**	0.783**	0.880**
BimMF	1					−0.124**	0.309**	−0.173**	−0.002^{NS}
	≥2					−0.082**	0.295**	−0.201**	0.015**
MF0–15	1						0.412**	0.520**	0.527**
	≥2						0.529**	0.579**	0.636**
MF15–30	1							0.794**	0.811**
	≥2							0.780**	0.790**
MF30–60	1								0.894**
	≥2								0.811**

MY – milk yield (kg); AMT – actual milking time (min); MTd – milking time difference (min); AMF – average milk flow (kg/min); BimMF – bimodal milk flow (%); MF0–15 – milk flow between first 0–15 s of milking (kg/min); MF15–30 – milk flow between 15–30 s of milking (kg/min); MF30–60 – milk flow between 30–60 s of milking (kg/min); MF60–120 – milk flow between 60–120 s of milking (kg/min); $P < 0.01$ = **; $P < 0.05$ = *; NS – no significance

Table 3. Evaluation of milkability parameters for the effect of lactation peak group (LPG), parity and interaction between LPG and parity (LSM ± SEM)

LPG	PARITY	MY, kg	AMT, min	MTd, min	AMF, kg/min	BimMF, %
0–30		16.62 ± 0.092^{B}	8:02 ± 0:03^{A}	2:09 ± 0:04^{A}	2.14 ± 0.017^{D}	22.94 ± 1.073^{A}
30–60		17.63 ± 0.037^{A}	8:07 ± 0:01^{A}	2:00 ± 0:01^{A}	2.36 ± 0.007^{A}	18.60 ± 0.446^{B}
60–90		16.47 ± 0.038^{B}	7:44 ± 0:01^{B}	1:50 ± 0:02^{B}	2.25 ± 0.008^{C}	17.59 ± 0.449^{B}
90–120		16.42 ± 0.042^{B}	7:21 ± 0:02^{C}	1:19 ± 0:02^{C}	2.32 ± 0.008^{B}	25.17 ± 0.485^{A}
P-value (LPG)		<0.01	<0.01	<0.01	<0.01	<0.01
	1	14.63 ± 0.054^{B}	7:32 ± 0:02^{B}	1:57 ± 0:02^{A}	2.08 ± 0.010^{B}	18.54 ± 0.635^{B}
	≥2	18.95 ± 0.034^{A}	8:05 ± 0:01^{A}	1:42 ± 0:01^{B}	2.45 ± 0.006^{A}	23.61 ± 0.386^{A}
P-value (PARITY)		<0.01	<0.01	<0.01	<0.01	<0.01
0–30	1	14.66 ± 0.165^{E}	7:34 ± 0:06^{E}	2:10 ± 0:06^{A}	2.04 ± 0.031^{E}	22.92 ± 1.946^{B}
30–60	1	15.62 ± 0.068^{D}	8:02 ± 0:03^{C}	2:15 ± 0:03^{A}	2.15 ± 0.013^{D}	15.86 ± 0.827^{C}
60–90	1	14.03 ± 0.057^{F}	7:29 ± 0:02^{E}	1:59 ± 0:02^{B}	2.03 ± 0.011^{E}	14.96 ± 0.686^{C}
90–120	1	14.19 ± 0.063^{F}	7:03 ± 0:02^{F}	1:25 ± 0:02^{C}	2.11 ± 0.012^{D}	20.42 ± 0.736^{B}
0–30	≥2	18.58 ± 0.082^{C}	8:29 ± 0:03^{A}	2:08 ± 0:03^{A}	2.24 ± 0.015^{C}	22.95 ± 0.937^{B}
30–60	≥2	19.65 ± 0.037^{A}	8:13 ± 0:01^{B}	1:46 ± 0:01^{B}	2.56 ± 0.007^{A}	21.34 ± 0.421^{B}
60–90	≥2	18.91 ± 0.059^{B}	7:58 ± 0:02^{D}	1:40 ± 0:02^{B}	2.46 ± 0.011^{B}	20.22 ± 0.673^{B}
90–120	≥2	18.64 ± 0.065^{C}	7:39 ± 0:02^{E}	1:13 ± 0:03^{C}	2.52 ± 0.012^{A}	29.92 ± 0.735^{A}
P-value (LPG×PARITY)		<0.01	<0.01	<0.01	<0.01	<0.01

LSM – least squared means; SEM – standard error of least squared means; LPG – lactation peak groups; MY – milk yield (kg); AMT – actual milking time (min); MTd – milking time difference (min); AMF – average milk flow (kg/min); BimMF – bimodal milk flow (%); $^{A\text{-}F}$ – values with different superscripts within the same column are significantly different at $P < 0.01$ (separately for each effect and interaction)

rous cows (2.15 and 2.11 kg/min, respectively for LPG30–60 and LPG90–120). For multiparous cows, the highest AMF was stated for LPG30–60 and LPG90–120 (2.56 and 2.52 kg/min, respectively). As expected, an existing strong relationship between MY, AMT and AMF was found regardless of parity (Table 2).

In the BimMF evaluation (Table 3), in overall the primiparous cows showed more favourable (lower) results than the multiparous cows ($P_{\text{PARITY}} < 0.01$). The highest occurrence of BimMF for the primiparous cows was observed for LPG0–30 and LPG90–120 (22.92 and 20.42%, respectively; $P < 0.01$). For the multiparous cows, the significantly highest occurrence was observed for LPG90–120 with 29.92%. The lowest BimMF (15.86 and 14.96%, respectively; $P < 0.01$) were achieved by primiparous cows in LPG30–60 and LPG60–90. For multiparous cows in LPG0–30, LPG30–60 and LPG60–90, there was no statistical difference in the occurrence of BimMF; however, these groups also did not differ from primiparous cows in LPG0–30 and LPG90–120.

Results for partial milk flows are shown in Table 4. In overall, for each partial milk flow the highest values were observed for multiparous cows ($P_{PARITY} < 0.01$).

LPG30–60 and LPG90–120; $P < 0.01$). Whereas the highest value for the primiparous for MF30–60 was only in LPG30–60 (2.56 kg/min). For the multiparous cows the lowest partial milk flows were measured in LPG0–30 across all 120 s (0.14, 2.28, 2.58 and 2.92 kg/min, respectively for MF0–15, MF30–60, MF60–90 and MF60–120). Moreover, for the multiparous cows, the highest value of MF0–15 was in LPG90–120 (0.52 kg/min), whereas for the other MFs, the highest values were in both LPG30–60 and LPG90–120. These observations were also aligned with the results of the correlation analysis.

Table 4. Evaluation of partial milk flows (MF) for the effect of lactation peak group (LPG), parity and interaction between LPG and parity, kg/min (LSM ± SEM)

LPG	PARITY	MF0–15	MF15–30	MF30–60	MF60–120
0–30		0.11 ± 0.012^{C}	2.02 ± 0.027^{D}	2.43 ± 0.025^{D}	2.70 ± 0.026^{C}
30–60		0.31 ± 0.005^{A}	2.33 ± 0.011^{B}	2.80 ± 0.010^{A}	3.11 ± 0.011^{A}
60–90		0.24 ± 0.005^{B}	2.14 ± 0.011^{C}	2.58 ± 0.011^{C}	2.87 ± 0.011^{B}
90–120		0.33 ± 0.005^{A}	2.39 ± 0.012^{A}	2.68 ± 0.012^{B}	3.08 ± 0.012^{A}
P-value (LPG)		<0.01	<0.01	<0.01	<0.01
	1	0.14 ± 0.007^{B}	1.92 ± 0.016^{B}	2.41 ± 0.015^{B}	2.64 ± 0.015^{B}
	≥2	0.35 ± 0.004^{A}	2.53 ± 0.010^{A}	2.83 ± 0.009^{A}	3.24 ± 0.010^{A}
P-value (PARITY)		<0.01	<0.01	<0.01	<0.01
0–30	1	0.08 ± 0.021^{E}	1.76 ± 0.049^{E}	2.27 ± 0.045^{E}	2.48 ± 0.047^{E}
30–60	1	0.18 ± 0.009^{D}	1.98 ± 0.020^{D}	2.56 ± 0.019^{C}	2.78 ± 0.020^{D}
60–90	1	0.17 ± 0.007^{D}	1.89 ± 0.017^{E}	2.37 ± 0.016^{E}	2.56 ± 0.016^{E}
90–120	1	0.13 ± 0.008^{D}	2.04 ± 0.018^{D}	2.45 ± 0.017^{D}	2.71 ± 0.018^{D}
0–30	≥2	0.14 ± 0.011^{D}	2.28 ± 0.024^{C}	2.58 ± 0.023^{C}	2.92 ± 0.024^{C}
30–60	≥2	0.44 ± 0.005^{B}	2.68 ± 0.011^{A}	3.04 ± 0.010^{A}	3.43 ± 0.010^{A}
60–90	≥2	0.30 ± 0.008^{C}	2.40 ± 0.017^{B}	2.78 ± 0.016^{B}	3.17 ± 0.017^{B}
90–120	≥2	0.52 ± 0.008^{A}	2.74 ± 0.019^{A}	2.90 ± 0.018^{A}	3.44 ± 0.019^{A}
P-value (LPG×PARITY)		<0.01	<0.01	<0.01	<0.01

LSM – least squared means; SEM – standard error of least squared means; MF0–15 – milk flow between first 0–15 s of milking (kg/min); MF15–30 – milk flow between 15–30 s of milking (kg/min); MF30–60 – milk flow between 30–60 s of milking (kg/min); MF60–120 – milk flow between 60–120 s of milking (kg/min); $^{A\text{-}E}$ – values with different superscripts within the same column are significantly different at $P < 0.01$ (separately for each effect and interaction)

The lowest value was observed for the primiparous cows for MF0–15 in LPG0–30 (0.08 kg/min; $P < 0.01$). The highest values for MF0–15 were observed for primiparous cows in all other groups (LPG30–60, LPG60–90 and LPG90–120), while for multiparous cows the lowest value of partial milk flow was also for MF0–15 in LPG0–30 (0.14 kg/min) but the highest value was stated only for one group – LPG90–120 (0.52 kg/min).

Furthermore, the highest values for the primiparous for MF15–30 were in LPG30–60 and LPG90–120 (1.98 and 2.04 kg/min, respectively; $P < 0.01$); the similar pattern was observed also for MF60–120 (2.78 and 2.71 kg/min, respectively for

Discussion

The results of the present study show significant differences in selected parameters of milkability between primiparous and multiparous cows, as well as among LPGs. As we expected the primiparous cows achieved lower MY compared to multiparous cows, which was also confirmed in other research articles, such as the study of Genc et al. (2018). Tekerli et al. (2000) stated that in terms of MY, it is more advantageous to reach lactation peak in LPG30–60 regardless of parity. This was confirmed by Grayaa et al. (2019), who also added that the optimal lactation peak is before 100 DIM. Our results also point to the fact that multiparous cows, that peaked between 30–60 DIM, had higher MY and better milkability parameters. This was also observed in primiparous cows, therefore it is more appropriate, in terms of milk yield, for cows to reach lactation peak after 30 DIM but before 60 DIM as some milkability parameters worsen after this point. Jílek et al. (2008) found that primiparous cows reach lactation peak later, around the 6th–7th week. As our results suggest, cows that reached lactation peak too early, within LPG0–30, had lower MYs and achieved worse results in monitored milkability parameters, which corresponds to the statement of Vijayakumar et al. (2017) and Kopec et al. (2013). In their studies, they stated that for multiparous cows it is more appropriate to reach the lactation peak in the range between 30 and 60 DIM, while primiparous cows on average reached the lactation peak 10 DIM later in comparison to multiparous cows.

If the MY increases, the milking time is extended. This trend is also evidenced by the value of the difference between the lowest and highest MY and AMT. These differences can be explained, for example by younger dairy cows, which are related to the MY (Mulliniks and Adams, 2019). However, the largest differences in MY and AMT values were found in the multiparous cows in LPG30–60 and LPG60–90. Our results also showed that MY is positively correlated with cow parity but negatively with lactation peak day, as was also confirmed by Erskine et al. (2019). Guarín and Ruegg (2016) in their study stated that MY during each milking was positively associated with an increasing number of lactations, but negatively associated with an increasing number of DIM and delayed milk release. AMT results suggested that it would be more advantageous to achieve a lactation peak between 90–120 DIM for primiparous cows and 60–120 DIM for multiparous cows because the early peaking cows had prolonged AMT. Similar results were found by Hogeveen et al. (2001) who stated that more milk produced in less time is a prerequisite for dairy cows to have better profitability and better udder health. This is also confirmed by our results, which suggest that focusing on high-milk production does not worsen milkability. The overall high values of MTd found in our study could be related to primiparous cows starting their production life and getting used to milking.

Samoré et al. (2011) added that faster milk release may be associated with an increased occurrence of BimMF, as confirmed by our results for multiparous cows in LPG90–120, which had the highest occurrence of BimMF, the highest AMF and the fastest milk decrease. Martin et al. (2020) stated that differences between MY and milking time may deepen with increased MTd or greater deviation of time from expected milking time. The occurrence of bimodality is negatively associated with milk production, longer milking time and increased susceptibility to mastitis (Samoré et al., 2011). The occurrence of BimMF ranged from 16 to 29%, which was lower than in the studies of Sandrucci et al. (2007) with 35.8% or Samoré et al. (2011) with 33.8%. Lower occurrence of BimMF might be caused by the combined form of stimulation used in our study. The lowest occurrence of BimMF was between 30–90 DIM for both parity groups, although differences were not statistically significant. The differences were significant within the lactation peak, while within parity the differences were minimal, as confirmed by Juozaitienë et al. (2020).

In the experiment we observed higher milk flow for multiparous cows, which corresponds with the standard milk flows of Holstein cattle (Upton et al., 2019). The period in which the cows reached the highest lactation affected the AMF when early peaking cows had worse values for AMF. The evaluation of the AMF results shows that primiparous cows released less milk in the same amount of time than multiparous cows. The slow release of milk after the start of teat stimulation changed during lactation and also depended on the milking interval of the previous milking (Bruckmaier, 2001; Müller et al., 2011). An association between slow milk release and low milk yield has been demonstrated in the study of Erskine et al. (2019). Bruckmaier (2001) stated that during milking there are changes in the amount of milk released and also the process of milk release happens more often in the late stages of lactation. Weiss et al. (2003) added that the initial milk flow can serve as a predictor of cow readiness for milking.

Milk flow values during the first two minutes of milking suggest that primiparous cows have lower milk flow at the beginning of milking regardless of the day of lactation peak. On the other hand, late peaking, multiparous cows reached significantly higher values of milk flow in the first two minutes of milking, which was also observed in the study of Fahim et al. (2017). The development of partial milk flows during the first two minutes of milking corresponded with the previous trend of milk yield and milking time, which Dodenhoff and Emmerling (2008) also confirmed in their study. Fahim et al. (2017) observed a sharp increase in milk flow during the second minute of milking regardless of the parity of the cows. In our study, this sharp increase in milk flow was also observed, but much sooner – during 15–30 s after the start of milking. This could be explained by the fact that we used the Holstein breed, which is a fast milking dairy breed, or by the differences in pre-milking udder preparation. Dzidic et al. (2004a) stated that oxytocin is released during the minute after preparation of the teat for milking, which initiates milk secretion.

Dairy cows with a lower initial milk flow had a longer milking time and lower average milk flow (Mišeikienė et al., 2014). Lower milk flows at the beginning of milking in primiparous cows may be caused by slower stimulation of the teats than multiparous animals. Another reason might be the teat cistern capacity is larger for multiparous cows in comparison to primiparous cows (Edwards et al., 2014). This might be the reason for the initial increase in the milk flow of multiparous cows (Fahim et al., 2017). The milk stored in the cistern makes up about 20% of the total amount, which can be released quickly (Bruckmaier, 2001). Once the milk is released from the cistern, the flow rapidly decreases, which is causing a bimodal milk flow curve to occur. This lasts until the ejection reflex occurs and the milk begins to be released from the alveolar tissue, causing the milk flow to increase again (Edwards et al., 2014).

Conclusions

It was shown that there is no one ideal period of lactation peak for all milkability parameters. In terms of milk yield, lactation peak is optimal between 30–60 day in milk (DIM) regardless of parity. It was also confirmed that primiparous cows have lower milk yields, shorter milking times, fewer bimodal flow and lower milk flows within the first two minutes of milking compared to multiparous cows. For these reasons, it is important to perceive both parity groups with different intensities. The presented results can be used for further research in the area of Central Europe, as there is a potential in breeding and improving the management of dairy farming with regard to lactation peak, milk flow and milking efficiency.

Data availability

The original data of the paper will be available upon request to the corresponding author.

Conflict of interest

The authors declare that there is no conflict of interest.

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