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Differences between Jersey and Holstein cows in milking-induced teat prolongation during lactation

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Abstract: Factors consequential to milking-induced teat prolongation (MITP) were identified. Effects of breed, teat position, lactation number, lactation stage and their interactions were evaluated. The length of each teat before and after milking was measured seven times during lactation in 59 Holstein cows and 45 Jersey cows. Rear teats seemed to prolong more with the exception of rear left teats of Holstein cows. MITP of Holsteins was more balanced among quarters compared to Jerseys, where we observed significantly higher MITP of their rear teats. The pairs mostly had similar reactions even for different teat lengths, therefore for future studies evaluating one of each pair should be sufficient and more effective. Development of MITP during lactation showed more variability at the onset of lactation, followed by more uniform response at later stages. Lower MITP for higher parity cows was observed only in Holsteins. Overall, Jerseys achieved a significantly higher level of MITP, which suggests breed differences in reaction to milking. Effects identified in this study should be taken into consideration while designing future experiments in this area. In addition, our results suggest the future necessity to improve milking technology to allow group or even individual settings optimization based on breed, lactation stage, lactation number, and teat position.

Keywords: dairy cow; milking; teat length; teat position

The teat condition plays a considerable role in the incidence of mastitis infections (Gleeson et al. 2004). Forces applied to the teats during milking result in physiological and pathological changes of their tissue, which may counteract the normal teat defence mechanism (Zwertvaegher et al. 2011). A short-term negative effect of machine milking on the teat tissue may manifest itself by oedema. Subsequently, long-term stressful milking may create a callous ring around the teat orifice (Stadnik et al. 2010). Teats also tend to continually prolong and widen in the course of production life (Guarin and Ruegg 2016). Previous studies identified many teat morphological characteristics as a risk factor for udder health, traits like wide teat apex diameter (Guarin and Ruegg 2016), short and wide teat canal (Lacy-Hulbert and Hillerton 1995) or occurrence of hyperkeratosis (Neijenhuis et al. 2001). Also, milking-induced changes of some of these structures were subjects of various studies with focus on optimization of milking conditions or evaluation of its impact on udder health – e.g. teat barrel diameter (Zwertvaegher et al. 2013) or teat

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canal prolongation (Geishauser and Querengasser 2000). The impacts of milking machine on teats are not well defined and additional research is required to better understand the relationship between teat dimensions, teats reaction to milking, and their influence on mastitis (Guarin et al. 2017).

Zwertvaegher et al. (2013) found relationships between milking-induced thickening of teats and worsening of udder health. They have not been found for milking-induced teat prolongation (MITP) yet, although some studies suggest that the relationships between teat length, teat thickness, and liner dimensions are intertwined (O'Callaghan 2001; Gleeson et al. 2004). O'Callaghan (2001) stated that teats expand after entering the liner to fill the barrel of the liner, therefore liner dimensions greatly influence the teat reaction to milking. Variations in used liners combined with existing inter-breed differences in teat morphology and their reaction to milking might be the reason for different results coming for MITP from various studies (e.g., –6 to –3 mm (Hamann et al. 1993), 1 to 3.2 mm (Parilova et al. 2011), 2.5 to 2.6 mm (Stadnik et al. 2010), 2.6 mm (Guarin and Ruegg 2016), 4.8 mm (Zwertvaegher et al. 2013) and 5.17 to 11.62 mm (Gleeson et al. 2004)).

The greatest teat prolongation occurs during high milk flow and then the teats thicken as the milk flow is low to none (Isaksson and Lind 1992). Previous research in this area was mostly focused on evaluating the influence of various milking settings like vacuum level (Hamann et al. 1993; Ipema et al. 2005), critical milk flow for automatic detachment (Parilova et al. 2011) and teat liners (Gleeson et al. 2004). However, various cow organism related factors could affect milking-induced teat changes. Therefore, identifying these effects and taking them into consideration while designing next experiments is essential for future research in this area. The effects of breed, teat position, lactation number and lactation stage could be critical factors affecting the teat tissue reaction to milking. Thus, the aim of this study was to evaluate the influence of these factors and their interactions on MITP.

MATERIAL AND METHODS

Animals and measurements. At the start of the experiment, there were 59 Holstein cows (H) and 45 Jersey cows (J) in their first (n_H = 16, n_J = 26), second and subsequent (n_H = 43, n_J = 19) lactation with average number of 2.25 lactations for H and 2.13 lactations for J. The length of each teat on the udder was measured with a calliper immediately before pre-milking preparation and immediately after (< 1 min) evening milking from the teat end to the teat basis. MITP was calculated as a change in teat length due to milking in relative values. Teat measurements were done by the same person during the whole experiment. The first measurement for each cow took place during summer (July or August) within 17 days after calving. Subsequent measurements were carried out 4 weeks apart until the start of late lactation (147–170 days in milk (DIM)). The final measurement was done at the end of lactation (246–315 DIM). Overall, 7 measurements were performed for each dairy cow during lactation, with the exception of cows culled for various reasons from a production herd in the course of the experiment. These 7 measurements represented various lactation stages defined in DIM range as follows: LaSt1 = 1–17 DIM (n = 104); LaSt2 = 30–49 DIM (n = 99); LaSt3 = 57–78 DIM (n = 97); LaSt4 = 90–113 DIM (n = 95); LaSt5 = 115–140 DIM (n = 93); LaSt6 = 147–170 DIM (n = 91); LaSt7 = 237–314 DIM (n = 77). Data on daily milk yield, milking time (daily average) and average milk flow (daily average) related to the day of the measurements were taken from "in-line real-time" milk analysers (Afilab, Afifarm, Israel) and evaluated. Data on DIM, lactation number (1 or 2+) and breed for the tested cows were also recorded. Dairy cows were milked twice a day in a herringbone milking parlour with an automatic detachment system, where the critical milk flow was set to 0.5 kg/min for H and 0.42 kg/min for J. Pulsation ratio was set to 60 : 40 with 55 pulses/min. Vacuum level was set to 42 kPa. Both used liners had an orifice diameter of 23 mm. Evening milking started 8 h after finishing the morning milking. The milking machine was attached from the side using a positioning tool. Milking settings did not change during the experiment.

Statistical analysis. The data were analysed using SAS software (Statistical Analysis System, Version 9.3, 2011). The UNIVARIATE procedure was used to determine basic parameters. For further evaluation, the dataset was divided into three additional groups based on teat length before milking (short teats (ShorT) < 43.1 mm; medium teats (MediT) 43.1–52.1 mm; long teats (LongT) > 52.1 mm) according to arithmetic means and standard deviation (< x – ½ s, –½ s to +½ s, > x + ½ s). Subsequently,

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relative MITP of all teats, ShorT, MediT and LongT was detailedly evaluated using the MIXED procedure. The REG procedure (stepwise method) was used to select suitable factors for a model equation. The best model for evaluation was selected in line with the values of the Akaike Information Criterion (AIC). Fixed effects of breed, teat position (TPos), lactation number (LaNu), lactation stage (LaSt), breed × TPos interaction, breed × LaNu interaction and breed × LaSt interaction were included in the model equation. The model was improved by the repeated effect of animal. The difference was detailedly evaluated by the Tukey-Kramer test. The significance level of $P < 0.05$ was used to evaluate the differences between groups.

The model equation was set as follows:

$$y_{ijklmn} = \mu + a_i + b_j + c_k + d_l + f_m + ab_{ij} + ac_{ik} + ad_{il} + e_{ijklmn}$$

where:

y_{ijklmn} = value of dependent variable (MITP all teats, MITP ShorT, MITP MediT and MITP LongT)

μ = overall mean value

a_i = fixed effect of breed (for total dataset: i = H, n = 1440; i = J, n = 1184; ShorT group: i = H, n = 1099; i = J, n = 724; MediT group: i = H, n = 909; i = J, n = 782; LongT group: i = H, n = 872; i = J, n = 862)

b_j = fixed effect of LaNu (for total dataset: j = 1, n = 1124; j = 2+, n = 1500; ShorT group: j = 1, n = 651; j = 2+, n = 1172; MediT group: j = 1, n = 736; j = 2+, n = 955; LongT group: j = 1, n = 861; j = 2+, n = 873)

c_k = fixed effect of LaSt (for total dataset: k = 1, 3–17 DIM, n = 416; k = 2, 30–46 DIM, n = 396; k = 3, 63–77 DIM, n = 388; k = 4, 92–113 DIM, n = 380; k = 5, 121–137 DIM, n = 364; k = 6, 149–165 DIM, n = 372; k = 7, 286–314 DIM, n = 308; ShorT group: k = 1, 3–17 DIM, n = 273; k = 2, 30–46 DIM, n = 297; k = 3, 63–77 DIM, n = 286; k = 4, 92–113 DIM, n = 271; k = 5, 121–137 DIM, n = 248; k = 6, 149–165 DIM, n = 233; k = 7, 286–314 DIM, n = 215; MediT group: k = 1, 3–17 DIM, n = 273; k = 2, 30–46 DIM, n = 261; k = 3, 63–77 DIM, n = 252; k = 4, 92–113 DIM, n = 236; k = 5, 121–137 DIM, n = 224; k = 6, 149–165 DIM, n = 246; k = 7, 286–314 DIM, n =199; LongT group: k = 1, 3–17 DIM, n = 286; k = 2, 30–46 DIM, n = 234; k = 3, 63–77 DIM, n = 238; k = 4, 92–113 DIM, n = 254; k = 5, 121–137 DIM, n = 256; k = 6, 149–165 DIM, n = 265; k = 7, 286–314 DIM, n = 202)

d_l = fixed effect of TPos (for total dataset: l = left front, n = 656; l = left rear, n = 656; l = right front, n = 656; l = right rear, n = 656; ShorT group: l = left front, n = 592; l = left rear, n = 296; l = right front, n = 598; l = right rear, n = 337; MediT group: l = left front, n = 460; l = left rear, n = 410; l = right front, n = 427; l = right rear, n = 394; LongT group: l = left front, n = 260; l = left rear, n = 606; l = right front, n = 287; l = right rear, n = 581)

f_m = repeated effect of animals (n = 104 animals with different number of measurements from 1 to 7)

ab_{ij} = fixed effect of breed × LaNu interaction

ac_{ik} = fixed effect of breed × LaSt interaction

ad_{il} = fixed effect of breed × TPos interaction

e_{ijklmn} = random residual error

RESULTS

Data on milk yield, milking time, and average milk flow were collected on the measurements day. Average daily milk yield and average milking time for both breeds throughout the tested period are in Figure 1. H achieved average daily milk yield

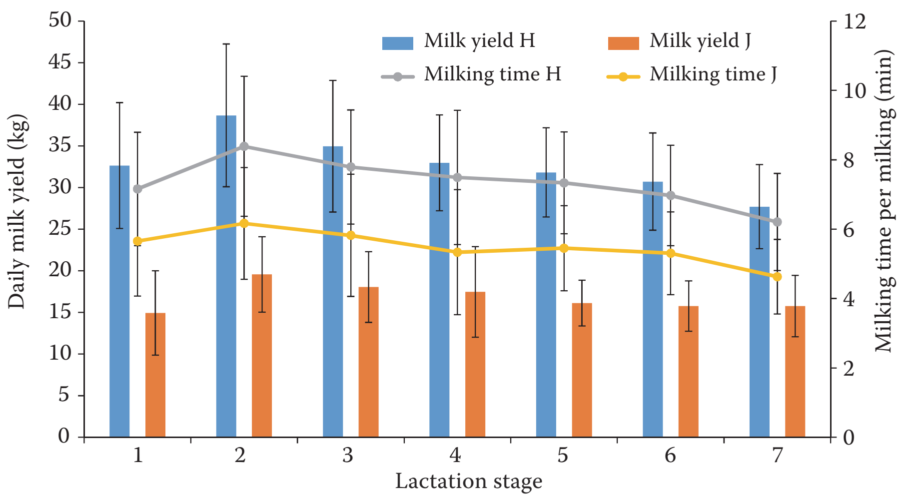

Figure 1. Basic statistical overview of mean daily milk yield and mean milking time per milking with standard deviation in tested breeds, and their development throughout lactation

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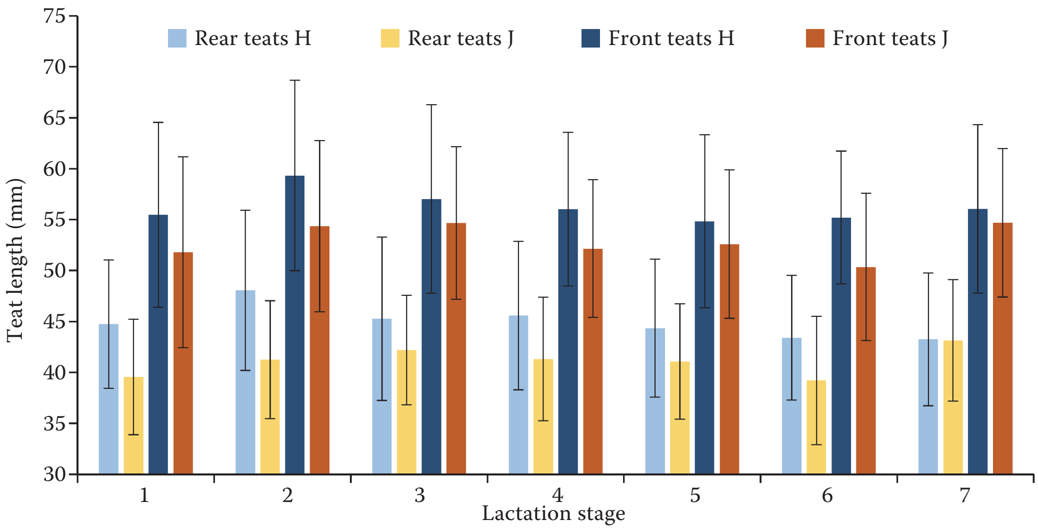

Figure 2. Basic statistical overview for mean teat length with standard deviation in tested breeds, and its development throughout lactation

of 33.05 kg, while J averaged at 16.83 kg. Milking took on average 7.33 min for H and 5.48 min for J. Average milk flow during lactation was 2.31 kg/min for H and 1.57 kg/min for J. Development of teat lengths during lactation is illustrated in Figure 2. Average teat length on the days of teat measurements was 50.61 mm for H and 47.03 mm for J. The ratio between rear and front teats was similar for both breeds (H = 0.81, J = 0.78), which indicates a high length imbalance between the pairs for both breeds.

The effects of breed, TPos, LaNu, and LaSt on MITP were evaluated using the MIXED procedure. The model equation explained 16–21.9% of variability and was statistically significant for MITP ($P < 0.05$). The effects of breed, LaNu, LaSt, TPos and interactions between breed and LaNu, breed and LaSt, and breed and TPos were statistically

Table 1. Effect of breed on milking-induced teat prolongation (MITP; %) based on pre-milking teat lengths (values are Least Squares Means ± standard error of the means)

Breed	All teats	Teat length groups		
		short teats	medium teats	long teats
Holstein	12.35 ± 0.38^{a}	8.76 ± 0.41^{a}	12.65 ± 0.49^{a}	17.23 ± 0.52
Jersey	15.23 ± 0.38^{b}	11.84 ± 0.47^{b}	15.50 ± 0.49^{b}	17.40 ± 0.50

^{a,b}different letters in columns mean statistical significance ($P < 0.05$)

Table 2. Milking-induced teat prolongation (MITP, %) based on pre-milking teat lengths in relation to breed and teat position (TPos) (values are Least Squares Means ± standard error of the means)

Interaction breed × TPos	All teats	Teat length groups		
		short teats	medium teats	long teats
H × left front	11.32 ± 0.70^{a}	9.44 ± 0.66^{b}	9.23 ± 0.83^{a}	20.38 ± 1.23^{a}
H × right front	12.15 ± 0.70^{a}	10.34 ± 0.64^{b}	10.39 ± 0.87^{a}	19.22 ± 1.16^{a}
H × left rear	12.68 ± 0.70^{a}	6.86 ± 0.85^{a}	15.44 ± 0.95^{b}	14.12 ± 0.75^{b}
H × right rear	13.23 ± 0.70^{b}	8.38 ± 0.78^{b}	15.53 ± 1.02^{b}	15.21 ± 0.76^{b}
J × left front	11.76 ± 0.75^{a}	10.76 ± 0.70^{b}	10.27 ± 0.99^{a}	16.17 ± 1.11^{b}
J × right front	12.79 ± 0.75^{a}	11.93 ± 0.70^{b}	12.31 ± 1.01^{a}	15.56 ± 1.06^{b}
J × left rear	17.24 ± 0.75^{c}	12.49 ± 1.14^{b}	18.84 ± 0.95^{b}	17.55 ± 0.78^{b}
J × right rear	19.13 ± 0.75^{c}	12.16 ± 1.15^{b}	20.57 ± 0.92^{c}	20.33 ± 0.79^{a}

H = Holstein breed, J = Jersey breed

$^{a-c}$different letters in columns mean statistical significance ($P < 0.05$)

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significant for MITP ($P < 0.05$) with few exceptions: the effects of LaNu and TPos were not significant for MITP ShortT, the interaction between breed and TPos was not significant for MITP MediT, and the effect of breed was not significant for MITP LongT. Concerning the results of the MIXED procedure, we focus on the effect of breed and its interactions with other effects.

Overall, J had significantly higher MITP compared to H (J = 15.23%, H = 12.35%, $P < 0.05$). MITP of J was also significantly higher for ShorT and MediT compared to H (Table 1).

Rear teats prolonged significantly more in J. The prolongation was relatively balanced among quarters in H, but rear teats also had a slight inclination to prolong more (Table 2). Rear right teats prolonged the most (P < 0.05). Overall, the prolongation of rear left teats of H did not significantly differ from that of front teats, but the individual teat length groups reacted differently ($P < 0.05$). Left and right positions within pairs mostly had a similar reaction with the exception of all and ShorT rear teats of H and MediT and LongT rear teats of J (Table 2).

The first lactation in H was characterized by significantly higher MITP of all teats and all teat length groups compared to higher parity cows (Table 3). A significant decline in MITP was observed only for

Table 3. Milking-induced teat prolongation (MITP, %) based on pre-milking teat lengths in relation to breed and lactation number (LaNu) (values are Least Squares Means ± standard error of the means)

Interaction breed × LaNu	All teats	Teat length groups		
		short teats	medium teats	long teats
H × 1	14.67 ± 0.64[a]	9.95 ± 0.71[a]	15.18 ± 0.81[a]	19.47 ± 0.81[a]
H × 2+	10.02 ± 0.41[b]	7.56 ± 0.40[b]	10.11 ± 0.54[b]	15.00 ± 0.58[b]
J × 1	15.67 ± 0.48[a]	10.60 ± 0.65[a]	16.44 ± 0.63[a]	17.46 ± 0.54[a]
J × 2+	14.79 ± 0.60[a]	13.08 ± 0.63[c]	14.56 ± 0.75[a]	17.34 ± 0.81[a]

1 = primiparous cows, 2+ = multiparous cows, H = Holstein breed, J = Jersey breed

[a,b]different letters in columns mean statistical significance ($P < 0.05$)

Table 4. Milking-induced teat prolongation (MITP, %) based on pre-milking teat lengths in relation to breed and lactation stage (LaSt) (values are Least Squares Means ± standard error of the means)

Interaction breed × LaSt	All teats	Teat length groups		
		short teats	medium teats	long teats
H × 1	2.94 ± 0.86[a]	0.56 ± 0.88[a]	3.36 ± 1.14[a]	7.40 ± 1.09[a]
H × 2	4.45 ± 0.89[a]	1.39 ± 0.86[a]	4.75 ± 1.13[a]	10.54 ± 1.29[a]
H × 3	13.91 ± 0.88[b]	9.10 ± 0.90[b]	14.00 ± 1.13[b]	20.98 ± 1.18[b]
H × 4	11.87 ± 0.90[c]	9.19 ± 0.90[b]	12.08 ± 1.19[b]	15.43 ± 1.170[c]
H × 5	19.39 ± 0.93[d]	15.81 ± 0.96[c]	19.19 ± 1.26[c]	23.87 ± 1.16[d]
H × 6	18.29 ± 0.92[d]	15.07 ± 0.98[c]	18.80 ± 1.17[c]	21.65 ± 1.16[b]
H × 7	15.57 ± 1.07[b]	11.28 ± 1.12[b]	16.33 ± 1.35[b]	20.77 ± 1.39[b]
J × 1	12.10 ± 0.96[c]	8.01 ± 1.18[b]	12.64 ± 1.17[b]	14.03 ± 1.14[c]
J × 2	17.65 ± 0.97[d]	12.24 ± 1.11[b]	18.54 ± 1.24[c]	20.91 ± 1.17[b]
J × 3	10.02 ± 0.10[c]	7.49 ± 1.07[b]	10.55 ± 1.29[b]	12.19 ± 1.25[a]
J × 4	17.48 ± 0.10[d]	12.83 ± 1.12[b]	18.13 ± 1.30[c]	20.28 ± 1.18[b]
J × 5	16.21 ± 0.10[b]	13.72 ± 1.14[c]	16.46 ± 1.28[b]	17.52 ± 1.18[c]
J × 6	16.25 ± 0.10[b]	14.01 ± 1.22[c]	15.45 ± 1.25[b]	17.86 ± 1.14[c]
J × 7	16.90 ± 1.04[b]	14.57 ± 1.11[c]	16.71 ± 1.35[b]	19.02 ± 1.28[b]

H = Holstein breed, J = Jersey breed

[a–d]different letters in columns mean statistical significance ($P < 0.05$)

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H (14.67–10.02%, $P < 0.05$). The greatest reduction of MITP was observed for MediT (H = –5.07%, $P < 0.05$; J = –1.88%, not significant). On the other hand, we did not find any significant differences in MITP between primiparous and multiparous J, with the exception of ShorT. MITP for ShorT of J significantly increased in higher parity cows ($P < 0.05$) (Table 3).

LaSt had a significant influence on MITP (Table 4). The smallest changes occurred at LaSt1 and LaSt2 in H. Although low MITP at LaSt1 was also observed in J, they achieved their lowest MITP at LaSt3 and their highest MITP at LaSt2. Generally, greater MITP was observed for LaSt5 and LaSt6 when all teat length groups of H showed more than 15% teat prolongation ($P < 0.05$). Increases in MITP were observed in H towards LaSt5, and then there was a decrease in MITP towards LaSt7. On the other hand, J cows kept a similar level of MITP after LaSt3 (16.21–17.65%) (Table 4).

DISCUSSION

In the present study, the average teat length in H cows (50.61 mm) was greater than in most other studies, e.g. 44.3 mm (Guarin and Ruegg 2016), 44.6–47 mm (Parilova et al. 2011), 45.5 mm (Strapak et al. 2015). However, a much higher average teat length (54.3 mm) was measured by Zwertvaegher et al. (2013). Our J cows had numerically smaller teats compared to H cows in this study (no statistical evaluation was performed). dos Santos et al. (2016) also observed that J cows had generally smaller udder morphometry compared to H and attributed it to their much smaller body frame. Although not directly evaluated as an effect, we noticed that the initial teat length could have influenced MITP in our study. Differences in the teat length of tested herds could have affected teat prolongation in studies of Zwertvaegher et al. (2013) and Guarin and Ruegg (2016). Zwertvaegher et al. (2013) reported average MITP of 9.2% (average teat length 54.3 mm) compared to 5.5% MITP (average teat length 44.3 mm) measured by Guarin and Ruegg (2016). In our study, we observed a higher level of MITP for both breeds compared to the above-mentioned studies. Interestingly, generally smaller teats of our tested J cows achieved a significantly higher level of MITP compared to H. The existing interbreed differences in teat dimensions and their reaction to milking were also described by Stadnik et al. (2010) and Genc et al. (2018). As observed in the present study, teats of different breeds react differently to similar milking conditions. In addition, we can reveal slight differences between breeds based on TPos, LaSt and LaNu factors.

Teat dimensions were influenced by TPos in the studies of Zwertvaegher et al. (2012) and Guarin et al. (2017). The length ratio between rear and front teats in our test groups showed a high degree of imbalance in length. Front teats longer by approximately 1 cm were also reported for example by Weiss et al. (2004), Strapak et al. (2015), and Guarin and Ruegg (2016). TPos also significantly affected MITP, when rear teats prolonged more. The other teat structures also reacted differently during milking based on teat position (Strapak et al. 2017). Naturally, there are a number of differences in milking characteristics between front and rear teats, which could potentially be consequential to MITP. Rear teats have significantly higher milk yield, milking time and milk flow compared to front teats (Weiss et al. 2004; Tancin et al. 2006), which could be the reason for higher MITP as suggested by Isaksson and Lind (1992) and Gleeson et al. (2004). The reaction to milking between left and right positions was similar in both breeds, therefore evaluating one of each pair for future studies should be sufficient and more effective. Our results also suggest that there is a possibility of milking settings optimization based on TPos, mainly in relation to discrepancies in morphology and milk yield.

The onset of lactation also showed higher MITP variability compared to the much more uniform reaction at later stages, which may be attributable to the resolving of physiologic udder oedema, which commonly appears 2 to 4 weeks after calving (Divers and Peek 2007). Lower MITP at the onset of lactation could be caused by oedema stiffened teats which could be less susceptible to prolongation. Also, udder oedema may indirectly influence the teat dimension measurements, either by altering the actual dimensions of the teat or by hindering the measuring methods from measuring them accurately (Zwertvaegher et al. 2012). We also observed distinctions between breeds in reaction to milking at various stages of lactation. Higher MITP of J may suggest a lower occurrence of physiologic udder oedema after calving as compared with H. We suggest excluding early lactating

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cows from studies focused on the teat reaction to milking to avoid result distortion. In addition, fluctuations of milk yield during lactation can be the reason to include LaSt as a factor for milking settings optimization. The basic muscle tone may gradually decrease by continuous milking at high vacuum levels as suggested by Hamann et al. (1993).

Cow teats have very high Poisson's ratio compared to other biological structures like aorta, which allows them to greatly change their shape under pressure. In mechanical terms, the cow teat tissue could be described as a fibrous structure rather than a homogeneous material like rubber, which is elongating at constant volume under pressure (Lees et al. 1991). It could definitely be summarized that all cows have a biological limit for a positive reaction to the vacuum. Exceeding these limits may lead to the teat tissue damage (Parilova et al. 2011) without further increase of the milk flow rate (Ipema et al. 2005). In future, we need to determine an optimal range of prolongation mainly with regard to udder health and milking settings optimization. Use of milking settings which are better adapted to cow's physiology could reduce the teat tissue damage and slow morphological changes during the production life (Parilova et al. 2011). Based on our results, the factor of breed should be considered important for the milking settings optimization. Ideally, milking settings should be adjusted individually for each cow and each milking, but there are still technological and sciential boundaries for this solution (Gasparik et al. 2018). Besides breed, factors like LaSt, TPos and teat morphology could be used to optimize milking for cow's needs. The changes in the udder may be irreversible if cows are exposed to improper milking for a long period, and these cows are at much higher risk of mastitis or/and culling (Parilova et al. 2011).

CONCLUSION

In our study we have found out that LaSt, LaNu and TPos significantly affect MITP. In addition, these effects showed interbreed variations and influenced MITP of J and H cows differently. Teat morphology could be another factor influencing their prolongation during milking. Inner teat morphology could also affect prolongation during milking and studies identifying these relations should be undertaken in future. Influential factors identified in this study should be taken into consideration while designing future experiments in this area to avoid data distortion for effects tested in your study. Our results also suggest that the next big step in improving milking technologies will be through optimization options for groups or even individual cows based on breed, LaSt, LaNu and TPos.

REFERENCES

Divers T.J., Peek S.F. (2007): Rebhun's Diseases of Dairy Cattle. Sounders, Elsevier, St. Louis, USA.

dos Santos S.K., Oliveira M.G., Noriler E.P., Vrisman D.P., Borges L.P.B., Santos V.J.C., Coutinho L.N., Teixeira P.P.M. (2016): Mammary gland ultrasound evaluation of Jersey cattle breed. Acta Scientiae Veterinariae, 44, 1–5.

Gasparik M., Duchacek J., Stadnik L., Novakova V. (2018): Impact of milking settings optimization on milk quality, milking time and milk yield in Holstein cows. IOP Conference Series: Materials Science and Engineering, 420, 012073.

Geishauser T., Querengasser K. (2000): Investigations on teat canal length in teats with milk flow disturbances. Journal of Dairy Science, 83, 1976–1980.

Genc M., Coban O., Ozenturk U., Eltas O. (2018): Influence of breed and parity on teat and milking characteristics in dairy cattle. Macedonian Veterinary Review, 41, 169–176.

Gleeson D.E., O'Callaghan E.J., Rath M.V. (2004): Effect of liner design, pulsator setting, and vacuum level on bovine teat tissue changes and milking characteristics as measured by ultrasonography. Irish Veterinary Journal, 57, 289–296.

Guarin J.F., Ruegg P.L. (2016): Pre- and postmilking anatomical characteristics of teats and their associations with risk of clinical mastitis in dairy cows. Journal of Dairy Science, 99, 8323–8329.

Guarin J.F., Paixao M.G., Ruegg P.L. (2017): Association of anatomical characteristics of teats with quarter-level somatic cell count. Journal of Dairy Science, 100, 643–652.

Hamann J., Mein G.A., Wetzel S. (1993): Teat tissue reactions to milking: Effects of vacuum level. Journal of Dairy Science, 76, 1040–1046.

Ipema A.H., Tancin V., Hogewerf P.H. (2005): Responses of milk removal characteristics of single quarters on different vacuum levels. ICAR Technical Series, 10, 49–55.

Isaksson A., Lind O. (1992): Teat reactions in cows associated with machine milking. Journal of Veterinary Medicine Series A, 39, 282–288.

Lacy-Hulbert S.J., Hillerton J.E. (1995): Physical characteristics of the bovine teat canal and their influence on

https://doi.org/10.17221/145/2019-CJAS

susceptibility to streptococcal infection. Journal of Dairy Research, 62, 395–404.

Lees C., Vincent J.F., Hillerton J.E. (1991): Poisson's ratio in skin. Bio-Medical Materials and Engineering, 1, 19–23.

Neijenhuis F., Barkema H.W., Hogeveen H., Noordhuizen J.P.T.M. (2001): Relationship between teat-end callosity and occurrence of clinical mastitis. Journal of Dairy Science, 84, 2664–2672.

O'Callaghan E.J. (2001): Influence of liner design on interactions of the teat and liner. Irish Journal of Agricultural and Food Research, 40, 169–176.

Parilova M., Stadnik L., Jezkova A., Stolc L. (2011): Effect of milking vacuum level and overmilking on cow's teat characteristics. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 59, 193–202.

Stadnik L., Louda F., Bezdicek J., Jezkova A., Rakos M. (2010): Changes in teat parameters caused by milking and their recovery to their initial size. Archiv Tierzucht, 53, 650–662.

Strapak P., Szencziova I., Stadnik L. (2015): Use of ultrasonography for evaluation of internal structures of udder and teats in dairy cows. Slovak University of Agriculture, Nitra, Slovakia. (in Slovak)

Strapak P., Strapakova E., Rusinova M., Szencziova I. (2017): The influence of milking on the teat canal of dairy cows determined by ultrasonographic measurements. Czech Journal of Animal Science, 62, 75–81.

Tancin V., Ipema B., Hogewerf P., Macuhova J. (2006): Sources of variation in milk flow characteristics at udder and quarter levels. Journal of Dairy Science, 89, 978–988.

Weiss D., Weinfurtner M., Bruckmaier R.M. (2004): Teat anatomy and its relationship with quarter and udder milk flow characteristics in dairy cows. Journal of Dairy Science, 87, 3280–3289.

Zwertvaegher I., Baert J., Vangeyte J., Genbrugge A., Van Weyenberg S. (2011): Objective measuring technique for teat dimensions of dairy cows. Biosystems Engineering, 110, 206–212.

Zwertvaegher I., Van Weyenberg S., Piepers S., Baert J., De Vliegher S. (2012): Variance components of teat dimensions in dairy cows and associated factors. Journal of Dairy Science, 95, 4978–4988.

Zwertvaegher I., De Vliegher S., Verbist B., Van Nuffel A., Baert J., Van Weyenberg S. (2013): Short communication: Associations between teat dimensions and milking-induced changes in teat dimensions and quarter milk somatic cell counts in dairy cows. Journal of Dairy Science, 96, 1075–1080.

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