MEASUREMENT OF TEAT STRUCTURES OF DAIRY COWS THROUGH ULTRASONOGRAPHY AND EXAMINATION OF MORPHOLOGICAL CHANGES IN TEATS CAUSED BY MACHINE MILKING

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Abstract. The aim of this study was to measure different characteristics of the cow teats and teat canals using ultrasonographic scanning, discover morphological changes in cow teats and recovery time of the teat tissue caused by machine milking. Overall 148 dairy cows of the Holstein (n = 100) and Simmental (n = 48) breed were investigated. Recovery of the teat internal parameters after milking was observed by ultrasonographic scanning. Teat canal length (TCL), teat canal diameter (TCD) and teat wall thickness (TWT) of 296 right front and rear teat were evaluated from 1776 measurements before (t0) and 0, 30, 60, 90 and 120 minutes after milking (t1 - t5). Maximum significant differences for the selected teat characteristics were found between t0 and t1 measurements. The highest restorations of the initial length 103.52% and 114.23% were detected 120 minutes after milking for front and rear teat canals in Holstein breed. Similar process of restoration was found in Simmental breed. All measured internal traits (TCL, TCD, TWT) showed decrease of values indicating the regeneration process of the teat and udder structures after the milking. However, teat canal length a teat wall thickness remained extended until the examination, what proved that 120 minutes period is not enough time for teat structures full recovery after milking. Significant relationships before milking between front teat canal diameter and daily milk yield (r = 0.348) and milk flow rate (r = 0.257) were confirmed. Negative correlations were found between teat canal length (front and rear) and milk production and milk flow rate before milking and immediately after milking. Significant effect of breed and recovery time was found in all internal traits, whereas cross factors daily milk production, recovery time and milk flow rate recovery time were significantly influenced only in relation to teat canal diameter.

Keywords: ultrasonography, teat, udder, milking traits

Introduction. The morphological characteristics of the mammary gland are important for both milk production and machine milking (Šlyžius et al., 2013). During machine milking of cows, there is a complicated interaction between the animal and the machine such that manipulation of milking conditions can have a substantial effect on milking performance and on udder health (Butler et al., 1992). The machine milking resulted in more simply the care of animals and efficient removal of milk without damage to the teat or gland, but on the other hand induced many disorders of udder (Twardon et al., 2001). The teat of farm animals serve the role of a valve regulating the outflow of milk and of a natural barrier for exogenous infections (Hamann and Mein, 1988). Hamann and Osteras (1994) demonstrated the importance of teat canal natural defense mechanism against udder pathogens. After milking, the defense mechanism of the teat canal to resist invasion and removal of mastitis causing pathogens from the canal is diminished (Gleeson et al., 2004). This is probably because teats are congested after milking and teats canal closes themselves more slowly (Neijenhuis et al., 2001).

(Hamann et al., 1993 and Geishauser and Querengässer, 2000) examined of the reaction of the teat to machine milking by traditional research methods describing the health state of the teat.

With different settings of the milking machine, such as vacuum level, level of cluster removal, and pulsation rate, teat tissue reaction clearly varies. Besides the teat tissue changes measurable after machine milking and recovery time of the teats is also an important issue (Hamann and Mein, 1988). In most literature reports the recovery time of the teats after milking fluctuate from 2 up to 8 hours (Neijenhuis et al., 2001; Strapak et al., 2017). The recovery time of the teat is important to determine a minimum milking interval. When a cow is milked whilst the teat tissue is not yet recovered, irreversible chronic changes of the teat tissue may occur (Hamann and Osteras, 1994).

The measurements of teat canal length and diameter were examined by different methods. McDonald (1975) used radiographic techniques, Grindal et al. (1991) and Lacy-Hulbert and Hillerton (1995) special sterile cannulas and Hamann et al. (1994), Bobic et al. (2014) and Strapak et al. (2017), applied ultrasonographic scanning. The last mentioned method is focused on the development of a methodology to obtain an image of intramammary structures (Franz et al., 2001).

Udder and teat scanning is generally performed for diagnosis of milk flow disturbances but also is increasingly used for examination and measurement of different anatomical structures (Neijenhuis et al., 2001; Franz et al., 2001; Paulrud et al., 2005; Szencziova and

Strapak, 2012; Bobic et al., 2014). Ultrasonographic scanning of the teat is used primarily in cows and sheep for the diagnostics of obstructions, stenoses, and the rosette of Furstenberg, fibrous changes in the area of the teat canal, or the boundary between the teat and gland cisterns (Fasulkov, 2012).

The use of ultrasonography of the udder allows for detailed measurements of the teat canal length and diameter, cistern, and the teat wall thickness (Gleeson et al., 2002; Slosarz et al., 2010; Stadnik et al., 2010; Szencziova and Strapak, 2012, Bobic et al., 2014). Many authors established a connection between mastitis in cows, the characteristics of the teat, the stage of lactation and the visualization of the teat canal (Grindal et al., 1991; Celik et al., 2008).

The aim of this study was to measure different parameters of the teat and teat canal by ultrasonographic scanning and examination of morphological changes in teats tissue caused by machine milking. The hypothesis of a relation between teat characteristics, milking traits and somatic cell score (SCS) was examined.

Material and methods. Dairy cows of Holstein (H, n = 100) and Simmental (S, n = 48) breed in the first, second or third and higher parity were included in the data set. Differences in the internal parameters of the teats – teat canal length (TCL), teat canal diameter (TCD) and teat wall thickness (TWT) were evaluated. The experiment was carried out on two farms with different milking equipment. All cows had clinically healthy udders. The cows were housed in a free stable with straw bedding and milked two times a day. Milking process in Holstein cows was done in herringbone milking parlour BouMatic 2 x 10 stall, electronic assembly Perfection 3000, number of pulse min. 60, vacuum level 42 kPa, pulsation rate - front teats 61:39 and rear teats 63:37. Automatic cluster take-off system at critical milk flow rate 0.2 kg/min was used.

Simmental cows were milked in herringbone milking parlors RDMoi 2x12, model BDS-378.2A – UNILAC 420, number of pulse 55/min., vacuum level 42.2 kPA, automatic cluster take-off system at critical milk flow rate 0.25 kg/min.

Ultrasonographic scanning

The scanning procedure was based on studies of Slosarz et al. (2010) and Stadnik et al. (2010). Ultrasound images of the longitudinal cross-section of teats from an Aloka Prosound 2 (Aloka Co., Ltd., Tokyo, Japan) scanner coupled with 7.5MHz linear probe (UST586-7.5MHZ) were made. An ultrasound probe was placed in a plastic cup filled with warm water (38 °C), into which teats were immersed (water bath technique). Exploration depth was 7 cm. Images were recorded in real time on a computer and archived in the form of video files. Later, were these files transformed into image.

Measurements

The measurements were taken on the evening milking on milking parlor six times through milking at regular time intervals: before milking, 0 (t1), 30 (t2), 60 (t3), 90 (t4) and 120 (t5) minutes after milking. The diameter, length of teat canals and the thickness of teat walls were measured on images recorded by a NIS 3.2 software (Laboratory Imaging s.r.o., Prague, Czech Republic). Teat canal length was measured in millimeters as the distance between the distal and proximal part (from the outer part to the inner part, with accuracy of 1 mm). The length of the teat canal was recorded in three consecutive times (triplicate scans of the same teat) and the mean of the measurements was used. Teat wall thickness was measured 10 millimeters over Furstenberg's rosette (Figure 1). Because of the practical matters, all the measurements were taken in right front and right rear teats. The experiment was performed on 296 teats with a total of 1776 teat measurements taken. Subsequently, somatic cell count and milk flow traits were measured. The sample of milk was taken from each cow for milk somatic cell count (SCC). Because of the intensive nature of the measurements only 10 cows per milking were scanned. The first measurement was made directly after routine pre-milking treatment (t0) and the second directly after removal of the milking cluster (**t1**). Repeatable scans of the same teats were taken at 30 minutes time intervals (**t2 - t5**) till 120 min. after milking. Measurements of three different properties of the internal structure of the teats were taken by one person.

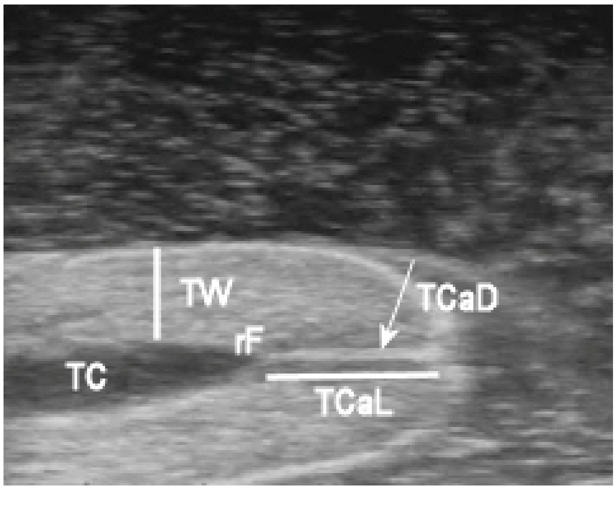

Fig. 1. **Ultrasonogprahic appearance of cow teat with the water bath method (vertical scan, 7.5 MHz linear probe): TCaL – teat canal length; TW – teat wall; TC – teat cistern; TCaD - teat canal diameter; rF – rosette of Furstenberg.** Photo: own research

Scans of the same teats (**t0 - t5**) were used to analyze the teat internal structure changes after milking and their relationship with milking traits and somatic cell score (SCS). All measured traits were recorded with help of milking software used at the farms. Evaluation of SCC was performed by NucleoCounter NC - 100 machine. The somatic cell count values were converted to a SCS in order to reach normal distribution by the following equation:

$$SCS = \log2 \text{ (Somatic cell count/100)} + 3 \qquad (1)$$

Statistical analyses

The average values and standard deviations of teat canal length, teat canal diameter and teat wall thickness were calculated in whole set of tested cows (n = 148), and specifically in dairy cows of Holstein and Slovak Simmental breed. The analysis of internal teat traits was evaluated by the average values of these variables on the right front and right rear teats.

Analyses of variance and Scheffe´s test were used to compare of the absolute changes of the internal traits of teats before milking, 0, 30, 60, 90, 120 min after milking. P-level for statistical significance was P<0.05. The data were analysed by ANOVA, statistical program SAS 9.2, Enterprise Guide 4.2 (SAS Institute, 2008). The relationships between TCL, TCD and TWT on the parity, daily milk yield, average milk flow and SCS were analyzed by correlation analysis.

To test the impact factors of breed, parity, teat position, recovery time, and cross factors daily milk production*recovery time, average milk flow rate*recovery time and SCS*recovery time to internal characteristics three linear models described by the following model equation were used:

$$Y_{ijklmnop} = \mu + breed_i + parity_j + teat_k + rec\_time_l + prod*rec\_time_m + flow*rec\_time_n + SCS*rec\_time_o + e_{ijklmnop} \quad (2)$$

where: $Y_{ijklmno}$ = teat canal length (teat canal diameter, teat wall thickness), μ = mean, $breed_i$ = the fixed effect of breed (i = H, S), $parity_j$ = the fixed effect of parity (j = 1, 2, 3) , $teat_k$ = the fixed effect of teat position (k = front, rear), rec_time_l = the fixed effect of recovery time (l = 0, 30, 60, 90, and 120 min), $prod*rec\_time_m$ = cross effect daily milk production*recovery time, $flow*rec\_time_n$ = average milk flow rate*recovery time, $SCS*rec\_time_o$ = SCS*recovery time, e_{jklmno} = random residual error.

Results.

Teat measurement

Results of the measurements of all the internal teat traits of two examined breeds are shown in Table 1. All the observed internal traits of the teat showed higher mean values for Simmental cows (SS), except the teat canal diameter, which showed higher average values for Holstein dairy cows (H). Simmental cows had in general longer teat canals in front teats about 14.28% and in rear teats by 4.95% as well as thicker teat walls in front teats about 12.64% and 14.99% in rear teats in comparison with H breed. On the other hand, cows of Holstein breed showed a wider teat canals about 2.8% greater than in rear teats. On this basis, it can be stated that cows of Holstein breed showed shorter and wider teat canals and teat walls thickness compared to dairy cows of SS breed.

Table 1. **Measurements of internal teat characteristics from two breeds (mm)**

		Holstein					Simmental				
		n	mean	min	max	sd	n	mean	min	max	sd
Teat canal length	Front teat	100	11.88	7.18	16.56	1.59	48	13.15	9.33	17.60	1.76
Teat canal diameter		100	1.14	0.93	1.46	0.11	48	1.09	0.96	1.28	0.07
Teat wall thickness		100	7.10	4.14	11.40	0.05	48	8.23	5.01	13.41	1.56
Teat canal length	Rear teat	100	11.62	3.66	16.23	1.90	48	12.48	7.14	18.00	2.10
Teat canal diameter		100	1.14	0.92	1.44	0.09	48	1.09	0.97	1.27	0.06
Teat wall thickness		100	7.16	4.33	11.01	1.17	48	8.37	5.01	12.50	1.36
n - number of observation, sd - standard deviation											

Recovery of the cow teats after milking

The internal characteristics of teats (TCL, TCD, TWT) and their changes dependent on time of measurement and breed are presented in Figures 2 - 7. Recovery of the teat after milking is very clearly demonstrated due to intensive measurements. The most significant differences in internal proportions were determined within those values measured before (t0) and immediately after milking (t1) for both breeds (P<0.05).

The average length of the front teat canal was increased by milking from 10.79 mm before milking to 12.93 mm immediately after milking in Holstein breed; representing an elongation of 19.83%. The rear teats showed elongation of 31.75% (Figure 2). The extension of the front and rear teat canals diameter immediately after milking in comparison with before milking was equal (8.18%) (Figure 3). The average wall thickness of the front teats in t0 reached 6.17 mm, while the influence of milking caused extension up to 7.96 mm, representing an increase up to 29.01%. Similar trend was detected in the rear teat wall thickness (Figure 4).

Prolongation of the teat canal length in Simmental breed was 23.97% and 38.16% for front and rear teats, respectively (Figure 5). Teat canal diameter reached elongation 9.52 % (front) and 8.57% (rear) (Figure 6) and teat wall thickness 35.97% and 32.87% for front and rear teats (Figure 7).

By our examination, all of measured parameters showed a decrease, indicating the regeneration process of the teat and udder structures after the milking. All these parameters remained extended until the examination with the exception of teat canal diameter, what proved that 120 min time period is not enough time for teat structures full recovery after milking. The slightest regeneration was found in teat canal length in H breed where the value reached 103.52 and 114.23% of origin length for front and rear teats, respectively (Figure 2). Similar tendency was found also in SS breed. On the other hand the most regenerative trait seems to be the teat canal diameter, with shows full recovery after 120 minutes compared with value before milking in both breeds (Figure 3 and Figure 6).

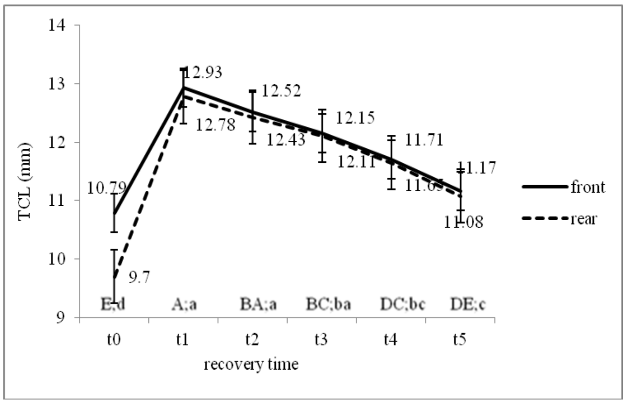

Fig. 2. **Changes of the front and rear teat canal length (TCL) of Holstein breed, before and after milking.** Significance is represented by different capital letters (front teat) and different small letters (rear teat) (P<0.05)

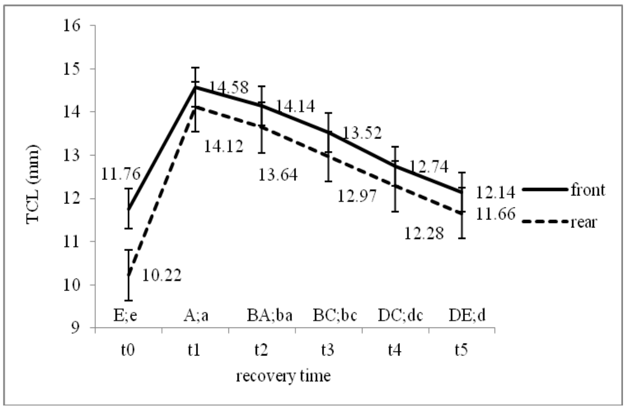

Fig. 3. **Changes of the front and rear teat canal length (TCL) of Simmental breed, before and after milking.** Significance is represented by different capital letters (front teat) and different small letters (rear teat) (P<0.05)

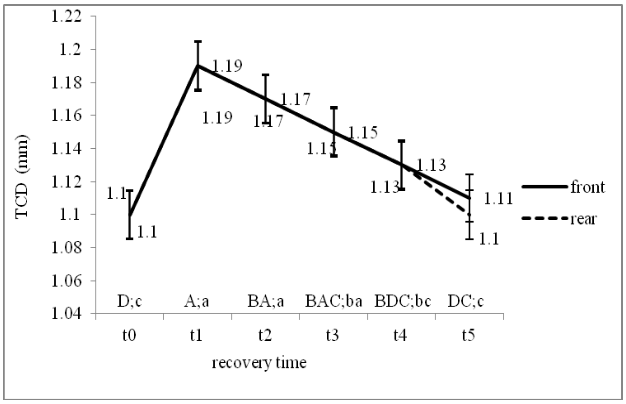

Fig. 4. **Changes of the front and rear teat canal diameter (TCD) of Holstein breed, before and after milking.** Significance is represented by different capital letters (front teat) and different small letters (rear teat) (P<0.05)

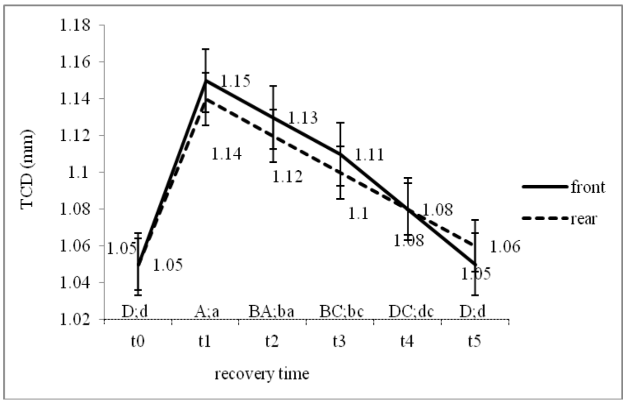

Fig. 5. **Changes of the front and rear teat canal diameter (TCD) of Simental breed, before and after milking.** Significance is represented by different capital letters (front teat) and different small letters (rear teat) (P<0.05)

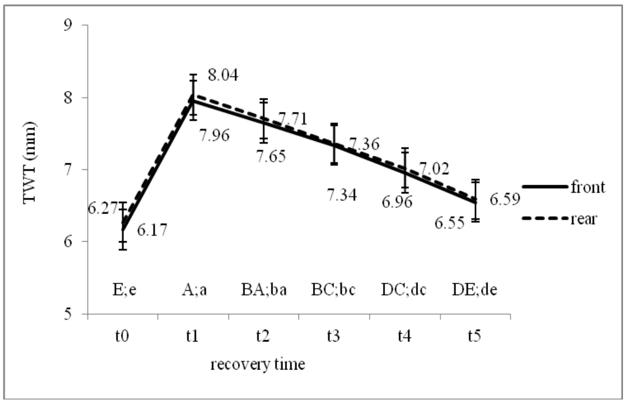

Fig. 6. **Changes of the front and rear teat wall thickness (TWT) of Holstein breed, before and after milking.** Significance is represented by different capital letters (front teat) and different small letters (rear teat) (P<0.05)

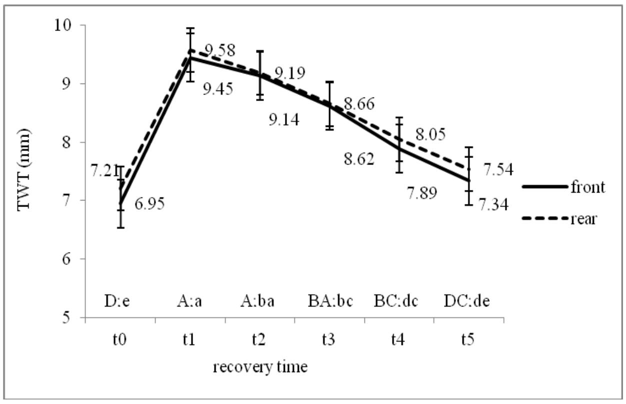

Fig. 7. **Changes of the front and rear teat wall thickness (TWT) of Simental breed, before and after milking.** Significance is represented by different capital letters (front teat) and different small letters (rear teat) (P<0.05)

Correlations

Correlation analysis of the relationship of traits such as the parity, daily milk yield, average milk flow, somatic cell score and the internal characteristics of the teats at each measured time were evaluated (Table 2). Within the correlation analysis, moderate relationship before milking between TCD of the front teats and daily milk yield (r = 0.348) and milk flow rate (r = 0.257), respectively were found. Positive relationship immediately after milking was found between TCD of the front teats and milk production (r = 0.335) and milk flow rate (r = 0.259). The same tendency was confirmed after 30 minutes. The correlation was found at 90 and 120 minutes time measurement after milking between TCD and milk production (r = 0.376 and r = 0.371), milk flow rate (r=0.270 and r=0.278) (Table 2).

Negative correlations was found between TCL of the rear teats, milk production and milk flow rate before milking (r = -0.248; r = -0.239) and immediately after milking (r = -0.257; r = -0.342), confirming the findings that cows with higher milk production and faster milk flow rate are having shorter teat canals (Table 2).

Relationship parity with internal teats characteristics was weak. A negative correlation between TCD of front teats and parity before milking (r = -0.17), immediately after milking (r = -0.19) and in other measured time intervals after milking was found (Table 2).

Table 2. **Pearson's coefficients of correlation between the internal characteristics of teats and observed milking characteristics depends on time of measurement**

	Before milking						Immediately after milking					
Variable	TCL f	TCD f	TWT f	TCL r	TCD r	TWT r	TCL f	TCD f	TWT f	TCL r	TCD r	TWT r
P	0.019	0.170	0.091	0.037	-0.136	0.163	0.047	-0.190	0.062	0.08329	-0.106	0.163
DMY	-0.106	0.348	-0.129	-0.248	0.212	-0.180	-0.13	0.335	-0.11	-0.275	0.207	-0.124
AMF	-0.153	0.257	-0.14	-0.239	0.191	-0.241	-0.212	0.259	-0.231	-0.342	0.153	-0.289
SCS	-0.048	-0.07	0.032	0.115	-0.033	0.081	-0.051	-0.035	-0.066	0.044	-0.019	-0.078
	30 minutes after milking						60 minutes after milking					
P	0.064	-0.172	0.073	0.098	-0.116	0.135	0.055	-0.190	0.068	0.058	-0.142	0.112
DMY	-0.151	0.333	-0.105	-0.292	0.177	-0.147	-0.166	0.343	-0.103	-0.274	0.216	-0.136
AMF	-0.221	0.238	-0.211	-0.334	0.129	-0.285	-0.207	0.236	-0.209	-0.311	0.156	-0.278
SCS	-0.035	-0.087	-0.054	0.049	-0.014	-0.05	-0.02	-0.085	-0.032	0.078	-0.003	-0.01
	90 minutes after milking						120 minutes after milking					
P	0.012	-0.197	0.023	0.038	-0.16	0.118	-0.104	-0.192	-0.001	0.033	-0.031	0.136
DMY	-0.144	0.376	-0.066	-0.276	0.214	-0.129	-0.051	0.371	-0.063	-0.259	-0.016	-0.113
AMF	-0.169	0.270	-0.143	-0.297	0.162	-0.251	-0.05	0.278	-0.114	-0.260	0.073	-0.230
SCS	-0.005	-0.08	-0.013	0.083	-0.02	0.003	-0.033	-0.064	0.013	0.099	0.05	0.001
P – parity; DMY – daily milk yield; AMF – Average milk flow; SCS - somatic cell score; TCL f – front teat canal length; TCD f – front teat canal diameter; TWT f –front teat wall thickness; TCL r - rear teat canal length; TCD r – rear teat canal diameter; TWT r –rear teat wall thickness; All correlations were signinificant												

GLM analysis of risk factors affecting internal measurements of the teat

The impact of the selected effects on the internal traits of the teats was calculated according to linear model Eq. (2).

A significant effect of breed on TCL (F = 86.35), TCD (F = 16.7) and TWT (F = 343.26) and recovery time on TCL (F = 80.05), TCD (F = 33.83) and TWT (F = 89.88) (Table 3) was found. Cross factors daily milk production * recovery time and milk flow rate * recovery time were significant influenced only on the teat canal diameter (F=3.36 and F = 4.07) (Table 3).

Discussion. Ultrasonography of teats in cows is the best solution for teat research as it is a noninvasive form, with minimal restrain of the animals. Ultrasonographic examination is easy to perform and has the advantage of allowing maintenance and sequential examination of the experimental animals, with increased welfare. In our experience, the scanning equipment was relatively easy to use and it could be also used for instance, to evaluate the effects of different milking techniques, liners, and milking machine settings for the reaction of the teat. Several scientific publications deal with the acute response of the teat tissue to machine milking (Gleeson et al., 2002; Slosarz et al., 2010).

In this study the mean values of the observed internal traits are different from those reported earlier (Grindal et al., 1991; Hamann et al., 1994; Klein et al., 2005). Differences can be observed in the teat canal length and teat canal diameter. These outcomes can be explained by the use of different kind of measuring method and mechanical manipulation of the teats. Further reasons could be the different time of examination, parity, and genetic differences between the examined breeds. Celik et al. (2008) found teat canal length in Holstein cows to average 11.51 mm, Neijenhuis et al. (2001) 11.09 mm, Bobic et al. (2014) 12.37mm (front) and 12.27 mm (rear). Klein et al. (2005) reported 15.7 mm long teat canal in Brown Swiss cows (longer than in our study). Geishauser and Querengässer (2000) state shorter average length of teat canal in various breeds (8 mm). In our study, we found narrower teat canal diameter than Klein et al.

(2005) in various breeds. Teat wall thickness in Holstein cows was thinner in comparison with finding by Neijenhuis et al. (2001). Bobic et al. (2014) stated higher values of the teat wall thickness in both, Holstein and Simental breeds.

Table 3. **GLM analysis of factors affecting internal traits of the teat**

Source	DF	Type III SS	Mean Square	F Value	Pr > F	R^2
Teat canal length						
Breed	1	204.2282617	204.2282617	86.35	<.0001	0.36
Parity	2	19.1606614	9.5803307	4.05	0.0176	
Teat position	1	66.7275127	66.7275127	28.21	<.0001	
Rec_time	5	946.5819955	189.3163991	80.05	<.0001	
Prodution*rec_time	18	58.4667198	3.2481511	1.37	0.1346	
Milk flow*rec_time	18	11.1266388	0.6181466	0.26	0.9992	
SCS*rec_time	18	41.3066154	2.2948120	0.97	0.4919	
Teat canal diameter						
Breed	1	0.10083847	0.10083847	16.70	<.0001	0.30
Parity	2	0.03019296	0.01509648	2.50	0.0824	
Teat position	1	0.00108789	0.00108789	0.18	0.6713	
Rec_time	5	1.02126793	0.20425359	33.83	<.0001	
Prodution*rec_time	18	0.36546176	0.02030343	3.36	<.0001	
Milk flow*rec_time	18	0.44232242	0.02457347	4.07	<.0001	
SCS*rec_time	18	0.08188286	0.00454905	0.75	0.7567	
Teat wall thickness						
Breed	1	400.3932839	400.3932839	343.26	<.0001	0.43
Parity	2	14.7542454	7.3771227	6.32	0.0018	
Teat position	1	3.3740474	3.3740474	2.89	0.0892	
Rec_time	5	524.2126556	104.8425311	89.88	<.0001	
Prodution*rec_time	18	16.9873271	0.9437404	0.81	0.6913	
Milk flow*rec_time	18	24.6878617	1.3715479	1.18	0.2727	
SCS*rec_time	18	25.9508398	1.4417133	1.24	0.2229	

The development of mammary infections depends on the pathogens passing defense line and entering the teat canal. Because of that it is advised to keep cows standing for at least 2 hours after they have been milked. When teats have an increased penetrability, they should not be in contact with any possible infection sources, such as bedding material of cubicles (Neijenhuis et al., 2001). The same authors also reported that full recovery of the teat may take between 3 and 8 hours which are in accordance with our findings. In our study the recovery of the teat tissue did not reach the initial length during two hours of examination. The teat canal length achieved 11.48 mm, what is 106.29% greater from initial length. Milking influence also extension teat canal diameter. We found, that two hour was sufficient time for full recovery of the teat canal diameter. Strapak et al. (2017) reported same result in 70 Holstein cows.

Unfortunately, the teat canal penetrability cannot be measured directly by ultrasonography. However, it is assumed that teat canal changes reflect teat canal penetrability. Therefore, parameters that estimate the changes in teat tissue are the best available parameters to estimate the teat canal penetrability under practical circumstances.

According to our results, the front teat canal length showed the highest relative changes immediately after milking (Table 2, Figure 2), which is in accordance with the findings of Neijenhuis et al. (2001), Strapak et al. (2017), Bobic et al. (2014) who found elongation of teat canal after milking to be about 19 – 28%.

A slight increase in the teat wall thickness was observed during the measurements. The mean values for wall thickness of front teats in Holstein breed were 6.17 mm before milking and 7.96 mm immediately after milking, which is comparable with Neijenhuis et al. (2001) and Bobic et al. (2014). Neijenhuis et al. (2001) reported that the full recovery of the teat wall could be more than 6 hours.

Nowadays it is very important to make efficient selection in cows targeted on high hereditary teat traits in order to reduce mastitis prevalence (Hamann and Burvenich, 1994). It has been proven that it is a correlation between teat status and udder health. Because of this relatively high hereditary trait of the teat and its effect on udder health, numerous studies concentrate on its internal structure. This study is the first one that used combination of the short term evaluation of the teat changes in most critical first 2 hours after milking and their relation to selected traits and udder health status.

The morphological structures of teat canal and especially the teat canal length may have effect on the development of udder infections. Klein et al. (2005)

recommend long and narrow teat canals to improve udder health. The authors also confirmed the significant effect of length and width of the teat canal when comparing healthy and infected udder quarters. The length of the teat canal is estimated as a negative parameter, which means that a longer teat canal is associated with a reduced risk of penetration of pathogens into the gland. Similar experimental results were found by Sekere et al. (2009). They examined non significant relationship between internal structures of the teats and somatic cell counts in milk, but reported lower levels of somatic cells in milk in cows with longer and wider teat canal. This results are in contrast with our work, when the length, diameter teat canal and teat wall thickness showed none relationship with somatic cell score.

We can agree that the teat canal length had a relation with daily milk yield and milk flow. Michel (1986) finds the optimum value of the teat canal between 8-12 mm, longer teat canals may negatively affect the milk ability of cows. Recommendations are consistent with the results of our work, when evaluated cows of Holstein and Simmental breeds had, with regard on milkability, the average length of teat canal from 10.27 to 11.78 mm. Loppnow (1959) reached to a similar conclusion. It has been stated that lower milkability is confirmed in cows with longer teat canals. In contrast, Klein et al. (2005) did not found any conclusive relationship between the internal structures of the teat and milkability. Geishauser and Querengässert (2000) confirmed the relationship between the length of teat canal and milk flow disorders. Bobic et al. (2014) stated negative correlations between average milk flow and teat canal length (teat wall thickness) which are comparable with our results. Many authors repeatedly reported that the teat canal length had a significant effect on the flow of milk through teat canal, which may be easy, or difficult (Biederman and Hubal, 1994). Loppnow (1959) reported that the teat canals were longer in hard milking cows in comparison to easy milking cows and also that the teat canal length has an effect on milking time since in cows with a longer teat canal milking time was significantly longer.

In this study, the significant influence of breed, parity and recovery time was found on all internal teat traits. Effect of teat position was documented as significant only on the teat canal length. Neijenhuis et al. (2001) also found significant effect of recovery time on all evaluated teat traits. Strapak et al. (2017) stated siginificant effect of parity, stage of lactation, teat position and recovery time on teat canal length and diameter. Klein et al. (2005) and Hamann and Burvenich (1994) reported effect of parity on teat canal increasing length.

Conclusion. Ultrasonography in cows is the best solution for teat research because of its noninvasiveness, allowing the visualization of the teat and its morphological changes with minimal restrain on the animals. In our study internal traits of the teats were evaluated depending on the time of measurement. Maximum differences for the selected teat parameters were found immediately after milking. The highest, nonsignificant relative changes after milking were found for the teat canal length. Significant relationship exists between teat canal diameter of the front teats and daily milk yield and milk flow rate. Teat canal length in all measurement times has a negative correlation with daily milk yield and average milk flow. This implies that cows with high milk production and faster milk flow rate are having shorter teat canals. In our work effect of breed and recovery time on the teat canal length, teat canal diameter a teat wall thickness was confirmed.

Based on the results, we can conclude that in terms of practical breeding for udder health and mastitis prevention it would be desirable to select cows with genetically longer teat canals. Although in the future it could be very important to focus further research in this field to gain more knowledge about the interactions among an udder, a teat, a milking traits and udder health status of cows.

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