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Ultrasonographic visualization of machine milking induced teat tissue changes in Holstein Friesian × Sahiwal crossbred dairy cows

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ABSTRACT

The study was conducted to observe the internal post-milking teat tissue changes and to evaluate recovery to pre-milking conditions, using ultrasonography. Left-sided teats of Holstein Friesian × Sahiwal crossbred dairy cows (n = 20) were scanned six times: before milking, immediately after milking, and at 1, 2, 3, and 4 hours after milking. Absolute and relative changes of teat canal length (TCL), teat diameter (TD), teat wall thickness (TWT) and teat cistern diameter (TCD) were measured. Machine milking significantly ($P<0.001$) affected all the measured teat parameters. There was a lengthening of the teat canal (19 - 25%), widening of the TD (19 - 20%), thickening of the teat wall (26 - 36%) and narrowing of TCD (51 - 52%). The time taken for the teats to return to their pre-milking state was significantly affected by teat position. The TWT, TCL and TD were recovered at 3 to 4 hours in the left front teats. In left hind teats, only TWT was recovered at 4 hours of milking. The deviations were highest immediately after milking for TD and TCD, and at 1 h after milking for TCL and TWT. We concluded that the time period of 4 hours is not sufficient for the complete recovery of the teats to the pre-milking state in Holstein Friesian × Sahiwal crossbred dairy cows.

Key words: Sahiwal cow; teat tissue; teat recovery; ultrasonography; machine milking

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Introduction

Although in India hand milking is still a common method of milking, nowadays, many dairy producers are opting for machine milking (MM) due to its practical and economic importance. However, the worldwide trend to improve milking speed has

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put considerable stress on teats. This will ultimately lead to teat tissue injuries, thereby increasing susceptibility to mastitis (ZECCONİ et al., 1992).

The role of the teats to act as barrier against intramammary infections (IMI) can adversely be affected through animal husbandry practices, such as milking techniques. Milk removal by catheter inserted into the teat canal, calf suckling and by hands cause none to very mild changes in teat tissues (HAMANN and MEIN, 1990; GLEESON et al., 2002). On the other hand, milk extraction by MM causes significant alterations in the physiological conditions (such as the development of oedema and congestion) of the teat tissue, which can alter the dimensions of internal teat structures such as the TCL, TWT, etc. (GLEESON et al., 2002; STADNİK et al., 2010; STRAPÁK et al., 2017).

In practical situations, teat tissue changes are the most appropriate way to assess teat canal penetrability (NEİJENHUİS et al., 2001). The teat canal remains open for a few hours after the completion of milking, and this opening creates suitable conditions for the penetration of microorganisms into the udder quarter. In most conventional milking systems, the return of the teat tissue to pre-milking conditions may take hours (NEİJENHUİS et al., 2001; GLEESON et al., 2002; STADNİK et al., 2010), which may depend on the milking machine settings (such as vacuum level, pulsation rate, cluster removal, level of overmilking) and cow related factors (such as breed, production level, and teat characteristics) (PAULRUD et al., 2005; STADNİK et al., 2010; FASULKOV, 2012; STRAPÁK et al., 2017). Recovery of the teats before the next milking is important to prevent chronic changes in the teat tissue. Therefore, it is important to assess how MM induces alterations in the physiological status of the teat.

There is a strong correlation between some teat form traits and udder health. Thus, it has been suggested that teats with desirable traits should be considered in selection criteria, in order to enhance resistance against mastitis in dairy cattle (SINGH et al., 2017). In the past, numerous studies concentrated on evaluating internal teat structures using conventional methods, such as radiography, endoscopy or cutometry, but these methods are difficult to use, laborious and may damage the udder tissue. Recently, ultrasonography has been used as an easily applicable and non-invasive method for evaluation of the internal teat tissue structures in cattle, sheep and goats (NEİJENHUİS et al., 2001; GLEESON et al., 2002; KUL and ERDEM, 2008; ALEJANDRO et al., 2014b; STRAPÁK et al., 2017). Ultrasonography of the teats has also been used to observe teat tissue reactions to the MM action (PAULRUD et al., 2005) and to monitor the return of the teat tissues from the post-milking to pre-milking condition (NEİJENHUİS et al., 2001; STADNİK et al., 2010; STRAPÁK et al., 2017). The technique can be applied for evaluation of the intramammary structures of dairy cows that potentially have a higher risk of mastitis (SEKER et al., 2009). Reasonably good quality images, particularly for the measurement of teat tissue structures, may be obtained with the help of a 7.5 MHz linear probe. On the other hand, inconsistent scientific data on the dimensions of the internal teat tissue parameters measured in these reports support the need for such studies. To the best of our knowledge, such studies are not available for cows from Holstein Friesian × Sahiwal crossbred dairy cows in India. The aim of this study was to evaluate, firstly, how MM affects the dimensions of internal teat tissues and, secondly, their recovery after milking to normal pre-milking physiological conditions in Holstein Friesian × Sahiwal crossbred dairy cows.

Materials and methods

Animals. Twenty healthy Holstein Friesian × Sahiwal crossbred dairy cows were included in the study, that were free from mastitis [without clinical (no visible or palpable changes in the udder tissue and no changes in milk consistency) or sub-clinical mastitis (California mastitis test negative)] and without any udder or teat abnormality. All the animals were kept at the university dairy farm situated at Ludhiana (Punjab State, India). The selected cows were also free from any limb problems (such as laminitis, hoof deformities, etc.) as they had to stand for long periods of time during the experiment. The cows were on average 99 days in milk (range 30 - 248) and the average lactation was 2.5 (range 1 - 5). All cows were loose-housed in a byre, on a daily ration of fresh roughage. The animals were offered concentrate during MM in a 2 × 5 tandem milking parlour (DeLaval, Tumba, Sweden). The cows were milked twice daily at 03.00 a.m. and 04.00 p.m. Pre-milking udder preparation consisted of cleaning the teats with water, followed by 2 - 3 strippings. The clusters were applied within 90 s of pre-milking udder preparation and then removed manually at the end of milking. During the study period, the average daily milk yield was 12.6 kg (range 9.1 - 15.3 kg).

Ultrasonographic measurements. The measurement of internal teat structures was performed by a portable ultrasound scanner (Agroscan AL, ECM, Noveko International Inc., France) using a 7.5 MHz linear rectal probe, as per the method used by GLEESON et al. (2002). In brief, the teats were first washed with lukewarm water to remove dirt. During scanning, the teat was immersed in a transparent plastic container filled with warm water (37 °C) and the probe with contact gel was held against this container to improve the quality of the ultrasound image. This technique prevents deformation of the teat during imaging, which may occur if the probe is placed directly on the surface of the teat (Fig. 1). The probe was manipulated to obtain clear longitudinal and cross-sectional images of the teat. The image was frozen and various teat tissue parameters, such as absolute values (millimeters) of teat canal length (TCL), teat diameter at the level of Furstenberg's rosette (TD), teat cistern diameter (TCD) and teat wall thickness (TWT), were measured (Fig. 2). During the evening milking, the left front (LF) and left hind (LH) teats were scanned just before milking (after udder preparation) and then at 0 (immediately after milking), 1, 2, 3 and 4 hours after milking. The relative changes in teat tissue parameters due to MM were calculated as: relative change (%): (post-milking value - pre-milking value)/pre-milking value × 100. Because of the intensive nature of the measurements, only two cows were scanned per day. Thus, 20 cows were scanned in 10 days. All measurements were taken by the same individual.

Fig. 1. A teat placed in a transparent plastic glass containing warm water with the probe held in a vertical position against the teat

Statistical analysis. The data were analyzed by computer statistical software (SAS version 9.1). Mean ± SE values were calculated for all the teat tissue parameters observed and the two sample *t*-test was used to compare the pre- and immediate post-milking absolute and relative mean values between LF and LH teats. Further, a model was built to study differences in time (immediately after milking and at 1, 2, 3, and 4 hours after milking) compared with the measurement (TCL, TD, TCD and TWT) just before milking. Teat parameter measurements at different time points of milking were entered into a model as response variables. The cow was considered as a random variable. The time of measurement and teat position (LF, LH) were put into the model as predictive variable. The data were analyzed by general linear model analysis of variance method, and least squares means were given.

The model fitted was:

$$Y_{ijk} = \mu + Cow_i + Time_j + TP_k + (Time * TP)_{jk} + e_{ijk}$$

Where:

Y_{ijk} = teat tissue parameter (TCL, TD, TCD and TWT),

μ = overall mean,

Cow_i = random effect of cow,

$Time_j$ = time of measurement; before milking, immediately after milking (0 h), and at 1, 2, 3 and 4 hours after milking,

TP_k = teat position; front teats and rear teats, and

e_{ijk} = residual random error

Results were expressed as statistically significant at $P<0.05$.

Results

A total of 240 ultrasound scans were available for analysis (two left-sided teats, 20 cows, six time periods). In all the examined teats, internal teat structures were visualized by ultrasonography (Fig. 2). The teat canal was seen as a hyperechogenic line on the apex of the teat. The Furstenberg's rosette, a hypoechoic structure, was demarcated as the point where the teat canal ends and the teat cistern starts. The outer wall of the teat was hyperechoic, followed by an inner hypoechoic muscular layer. The lumen of the teat cistern was filled with milk and appeared anechoic.

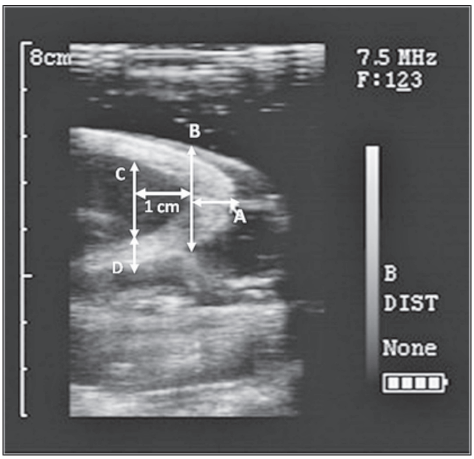

Fig. 2. Measurement of teat canal length (A); teat diameter at the level of Furstenberg's rosette (B); teat cistern diameter at 1 cm above the end of the teat canal (C); and teat wall thickness (D) at 1 cm above the end of the teat canal

The overall means of TCL varied from 7.72 to 13.2 mm and from 9.1 to 16.2 mm before and after milking (0 h), respectively. The TD average varied from 16.2 to 25.3 mm and 19.2 to 25.2 mm before and after milking, respectively, and TCD means varied from 6.9 to 16.8 mm and from 3.32 to 11.1 mm before and after milking, respectively. Lastly, the average of TWT varied from 5.1 to 11.8 mm and from 6.8 to 13.1 mm before and after milking, respectively. Table 1 shows the mean ± SE values of teat tissue parameters (TCL, TD, TCD and TWT) measured by ultrasound scans. Mechanical milking resulted in longer teat canals, thicker teats and teat walls, and smaller teat cisterns immediately after milking ($P<0.05$). The average increase in TCD (>50%) and TWT (>30%) because of milking was more than TCL (22%) and TD (19%). The absolute and relative means for the measured teat parameters did not vary significantly ($P<0.05$) according to teat position.

Table 1. The effect of machine milking on teat tissue parameters measured by ultrasonography before and immediately after milking

Teat tissue parameter	LF teats (n = 20)	LH teats (n = 20)	P-value	Overall (n = 40)
Before milking				
TCL (mm)	10.56 ± 0.35	10.14 ± 0.39	NS	10.35 ± 0.26
TD (mm)	20.81 ± 0.68	20.52 ± 0.59	NS	20.67 ± 0.44
TCD (mm)	12.17 ± 0.65	12.88 ± 0.48	NS	12.52 ± 0.40
TWT (mm)	7.43 ± 0.38	6.92 ± 0.34	NS	7.18 ± 0.25
After milking				
TCL (mm)	12.60 ± 0.43	12.57 ± 0.42	NS	12.58 ± 0.29
TD (mm)	24.63 ± 0.66	24.66 ± 0.66	NS	24.65 ± 0.46
TCD (mm)	6.09 ± 0.55	6.24 ± 0.45	NS	6.17 ± 0.35
TWT (mm)	9.16 ± 0.36	9.25 ± 0.34	NS	9.20 ± 0.25
Relative changes (%)				
TCL	19.5 ± 1.58	24.7 ± 2.09	NS	22.1 ± 1.36
TD	18.8 ± 1.16	20.5 ± 1.28	NS	18.8 ± 1.16
TCD	- 50.7 ± 2.54	- 52.1 ± 2.18	NS	- 51.4 ± 1.65
TWT	26.3 ± 3.99	36.2 ± 4.57	NS	30.8 ± 3.05

*Values are means ± SE; TCL = Teat canal length; TFD = Teat diameter at the level of Furstenberg rosette; TCD = Teat cistern diameter; TWT = Teat wall thickness; LF = Left front; LH = Left hind; NS = Non-significant

All teat parameters were significantly associated with the time of measurement after milking, and teat position had a significant effect on teat tissue recovery (Table 2). TCL and TD had recovered at 4 hours in LF teats ($P>0.05$). TWT had recovered at 3 hours and 4 hours in LF and LH teats, respectively ($P>0.05$). However, the recovery time was more than 4 hours for TCD in both LF and LH teats (P<0.05). The absolute means for the measured teat parameters did not differ significantly (P>0.05) between LF and LH teats at any of the time points of measurement. However, in general, the relative changes for teat tissue parameters throughout the post-milking period remained higher for LH teats as compared to LF teats (Fig. 3).

Table 2. Least squares means (± SE) of teat tissue parameters measured before and after milking at different hourly intervals

Teat tissue parameter	n	Time of measurement					
		Before	0 h	1 h	2 h	3 h	4 h
TCL							
LF	20	10.56[a] ± 0.37	12.59[b] ± 0.42	13.10[b] ± 0.48	12.89[b] ± 0.43	12.58[b] ± 0.44	12.44[ab] ± 0.50
LH	20	10.14[a] ± 0.37	12.57[b] ± 0.42	12.79[b] ± 0.48	13.03[b] ± 0.43	12.70[b] ± 0.44	12.15[b] ± 0.50
TD							
LF	20	20.81[a] ± 0.63	24.63[b] ± 0.66	24.49[b] ± 0.68	23.88[b] ± 0.74	23.91[b] ± 0.64	23.57[ab] ± 0.68
LH	20	20.51[a] ± 0.63	24.66[b] ± 0.66	24.58[b] ± 0.68	24.50[b] ± 0.74	23.91[b] ± 0.64	23.54[b] ± 0.68
TCD							
LF	20	12.17[a] ± 0.57	6.09[d] ± 0.50	7.27[bcd] ± 0.54	7.99[bcd] ± 0.56	8.87[bc] ± 0.68	9.55[b] ± 0.59
LH	20	12.87[a] ± 0.57	6.24[d] ± 0.50	8.12[bcd] ± 0.54	8.38[bcd] ± 0.56	8.54[bc] ± 0.68	9.61[b] ± 0.59
TWT							
LF	20	7.43[a] ± 0.36	9.16[b] ± 0.35	9.18[b] ± 0.36	8.99[b] ± 0.38	8.77[ab] ± 0.28	8.44[ab] ± 0.32
LH	20	6.92[a] ± 0.36	9.25[b] ± 0.35	9.54[b] ± 0.36	9.38[b] ± 0.38	8.72[b] ± 0.28	8.35[ab] ± 0.32

TCL = Teat canal length; TD = Teat diameter at the level of Furstenberg rosette; TCD = Teat cistern diameter; TWT = Teat wall thickness; LF = Left front teats; LH = Left hind teats; [a-e]: means without a common letter within a row indicate significant differences at P<0.05·

Among the observed teat tissue parameters, TCD and TWT showed greater changes over the study period (Fig. 3A and 3B, respectively). Immediately after milking, TCD decreased by approximately 50% in both teats (P<0.05) and 4 hours after milking, TCD was still considerably less by approximately 26% and 21%, respectively, for LH and LF teats. A similar, although slightly less marked effect of MM was also observed in relation to the measurement of TWT. Immediately after milking (0 h), the relative TWT of LH and LF teats was approximately 36% and 26%, respectively (P<0.05), and 3 hours after milking, the swelling was still substantial, with relative values being 29% and 21%, respectively, for LH and LF teats. On the other hand, less intensive changes in TCL and TD were noticed under the influence of MM (Fig. 3C and 3D, respectively). After milking, the teat canal was lengthened by 25% and 20% for LH and LF teats, respectively (P<0.05) and this dimension was still significantly (P<0.05) larger (20%) after 4 hours of milking in LH teats. The TD was increased by 21% and 19%, respectively, for LH and LF teats immediately after milking, while after 4 hours of milking, the diameter was still 15% more in LH teats (P<0.05).

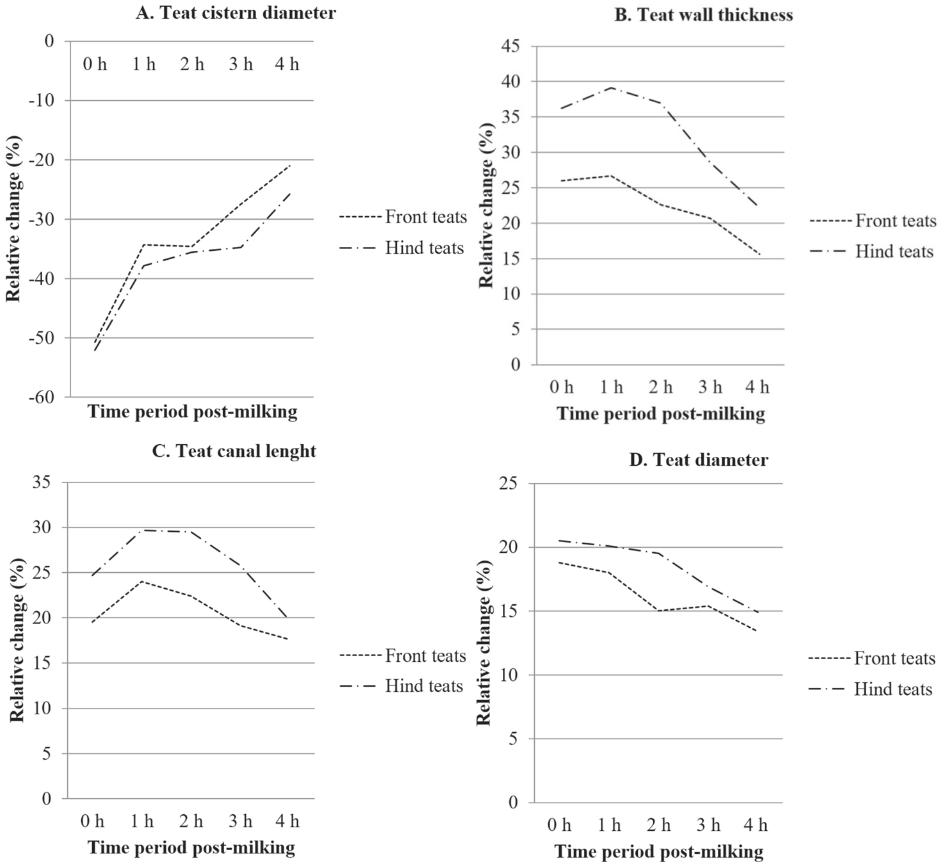

Fig. 3. Relative teat tissue changes (%) at different time periods post-milking; A - Teat cistern diameter at 1 cm above the end of the teat canal; B - Teat wall thickness at 1 cm above the end of the teat-canal; C - Teat canal length; and D - Teat diameter at the level of Furstenberg's rosette

Discussion

The mean values of the internal teat structures measured in this study were different from those reported earlier (NEİJENHUİS et al., 2001; GLEESON et al., 2002; KLEİN et al., 2005; KHOL et al., 2006; STRAPÁK et al., 2017). The dissimilarities in the results in the present, as well as previously reported studies, may be related to cow factors such as breed, stage of lactation, milk yield, teat shape and position, and udder health (NEİJENHUİS et al., 2001; KLEİN et al., 2005; PAULRUD et al., 2005; KHOL et al., 2006; STRAPÁK et al., 2017). In addition, the method of measurement (HAMANN et al., 1993; ALEJANDRO et al., 2014a), milking technique (GLEESON et al., 2002; ALEJANDRO et al., 2014a) and milking machine settings (GLEESON et al., 2004; REİNEMANN et al., 2008) may also affect teat tissue dimension. In spite of these factors, in general, milk removal during the milking process causes physiological changes (transient congestion and oedema) in the teat and it is presumed that teat tissue changes reflect teat canal penetrability (HAMANN and MEIN, 1988). These changes are more pronounced in machine milked animals (GLEESON et al., 2002; ALEJANDRO et al., 2014a). Severe alterations in the teat tissue may decrease the efficiency of the teat defence mechanism and lead to increased risk of new IMI's (ZECCONİ et al., 1992; GLEESON et al., 2004). It has been suggested that when teat end thickness increases more than 5%, the risk of IMI of the quarter is greater (ZECCONİ et al., 1992).

We observed lengthening of the teat canal, widening of the TD, thickening of the teat wall and narrowing of the TCD after MM, compared with the pre-milking values; this concurs with earlier reports (NEİJENHUİS et al., 2001; GLEESON et al., 2002). In this study, the overall average relative change in TCL according to milking was from 18 to 23%, in TD from - 0.5 to 18%, in TCD from 52 to 34%, and in TWT from 11 to 33%. Similar trends were also observed in previous studies. NEIJENHUIS et al. (2001) reported that the average relative change in teat parameters caused by milking were from 10 to 30% in TCL, from 2 to 10% in TD, from 50 to 3% in TCD, and from 20 to 50% in TWT. STADNIK et al. (2010) determined relative changes in teat length from 13.4 to 16.2%, from 18.4 to 24.1% in the area of the teat end, and from 14.6 to 19.7% in TWT. There is general consensus that the vacuum applied during the "D" phase of pulsation (milking phase) of MM causes an accumulation of blood and lymph in the teat end, which is removed during the massage phase by the compressive load applied by the liners (IDF, 1987). During times when the milk flow is low or there is none, the existing removal of blood and interstitial fluids may be inadequate, and congestion and oedema may develop (ANONYM, 1987).

In this study, the effect of teat position was not evident when comparing the absolute means for the teat tissue parameters observed post-milking with the pre-milking values. However, the relative changes from pre-milking values were more evident in LH teats than in LF teats. Similar to our results, KLEİN et al. (2005) also found non-significant differences between front and rear teats for TCL, TD, TWT and TD. However, STRAPÁK et al. (2017) found a significant effect of teat position on the TCL and TD. They found an average increase of TCL for right front and rear teats by about 20.5% and 32.9%, respectively, immediately after milking. Similarly, the teat canal widened by 9.0 and 9.1%, in the front and rear teats, respectively.

The overall relative changes in TCL (22%) were larger than that of TD (19%), which is in accord with the conclusion of NEİJENHUİS et al. (2001) that the teat tip is under more stress during milking in length than in width. Further, the changes in TD were relatively smaller compared with the other teat parameters, which corroborates with the results of NEİJENHUİS (2004). The TWT increased by 31% immediately after milking which was almost similar to the findings of NEIJENHUIS et al. (2001), who found an average increase in TWT by 34%. In a recent study in ewes, ALEJANDRO et al. (2014b) reported that the increase in TWT after milking could be due to the decrease in intramammary pressure. When milk is removed from the teat cistern, the intramammary pressure is decreased (HAMANN and MEIN, 1990), thus relaxing the stretched walls of the teat cistern, leading to an increase in TWT values. In this study, TWT and TCD showed the highest relative changes (31% and 51%, respectively) immediately after milking, as compared to TCL and TD. Both parameters changed through the milking process in the opposite direction. Milk is withdrawn from the teat cistern during milking. As a result, the teat cistern volume decreases and the TWT increases (NEİJENHUİS et al., 2001).

In the present study, the recovery time for TCL, TD, TCD, and TWT varied from 3 to >4 hours and the effect of teat position on the recovery time was observed. Our results may indicate that MM induces extensive changes in teat fluid dynamics, which continued for longer periods. O'BRİEN (1988) showed that teat sphincter closure takes place within 2 hours after milking, and it is generally assumed that the teats have fully recovered to pre-milking values at this time. However, NEİJENHUİS et al. (2001) and GLEESON et al. (2002) suggested that the process of teat recovery, as determined by ultrasonographic scanning, lasts 5 to >8 hours. According to HAMANN and MEIN (1990) and GLEESON et al. (2002), the differences in recovery time may depend on the milking systems used and MM settings. In this study, LH teats took more time to reach to their ideal (pre-milking) state. STRAPÁK et al. (2017) also observed a similar trend for the post-milking recovery of TCL in Holstein cows.

In general, the maximum relative changes of the different teat tissue variables were obtained immediately or 1 h after milking. The changes for TD and TCD were highest immediately after milking and for TCL and TWT at 1 h after milking. In cattle, NEIJENHUIS et al. (2001) observed the highest TWT and TCL values immediately after milking and at 2 hours, respectively, whereas ŚLÓSARZ et al. (2010) found maximum values of TWT and TCL immediately after milking, compared with 4 and 10 hours after milking, in goats. On the other hand, WÓJTOWSKI et al. (2006) obtained the highest TWT and TCL at 4 hours after machine milking in sheep. However, most variables did not reach pre-milking values at 4 hours, but their decrease indicates gradual recovery. While it could not be said that the teat tissue had recovered before the following milking, the fact that teat tissue recovery can take more than 4 hours or even up to 8 hours (NEIJENHUIS et al., 2001) is important when selecting ideal milking intervals. Milking with shorter intervals leaves less time for the teats to recover; thereby, leading to physiological dysfunction of the teat (HAMANN and ØSTERÅS, 1994; RASMUSSEN et al., 2001). It has generally been established that milk is continuously moved into the cisternal cavities during the inter-milking intervals. It may be likely that the shortening of the TCL, the widening of the teat cistern and the thinning of the teat wall are not 'recovery' of teat tissue from milking action but an opposite effect caused by the filling of the teats with milk, leading to stretching of the teat.

Conclusions

The results of the present study indicate that ultrasonography can be used as a modern and non-invasive tool to evaluate and estimate the degree of teat tissue reactions caused by milking. Teat cistern width and TWT were largely affected by MM, as compared to TCL and TD. The deviations were highest immediately after milking for TD and TCD, and at 1 h after milking for TCL and TWT. Hind teats took more time to recover as compared to front teats. Although the time period of 4 hours is not sufficient for the complete recovery of teat structures, their gradual return towards ideal state indicates the recovery of teats over time in Holstein Friesian × Sahiwal crossbred dairy cows. Further studies, using ultrasonography, may be conducted to examine the interrelationship between milking machine settings, milking induced physiological changes in the teat tissues, and quarter health status.

Conflicts of interest

The authors do not have any conflicts of interest to declare.

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SINGH, R. S., B. K. BANSAL, D. K. GUPTA: Ultrazvučni pregled promjena vimena uzrokovanih strojnom mužnjom mliječnih krava križanki između holštajnsko-frizijske i sahival pasmine. Vet. arhiv 89, 295-308, 2019.

SAŽETAK

Ovo je istraživanje provedeno kako bi se ultrazvukom uočile promjene u tkivu sisa nakon mužnje i procijenio njihov oporavak te vraćanje u stanje prije mužnje. Lijeve sise mliječnih krava križanki između holštajnsko-frizijske i sahival pasmine (n = 20) šest su puta ultrazvučno promatrane: prije mužnje, odmah nakon mužnje te 1, 2, 3 i 4 sata nakon mužnje. Mjerene su apsolutne i relativne promjene dužine sisnog kanala (TCL), promjer vimena (TD), debljina stijenke sisnog kanala (TWT) i promjer sisne cisterne (TCD). Strojna mužnja znakovito je (P<0,0001) utjecala na sve mjerene pokazatelje. Uočeno je produženje sisnog kanala (19 - 25 %), povećanje promjera vimena (19 - 20 %), zadebljanje stijenke vimena (26 - 36 %) i suženje sisne cisterne (51 - 52 %). Na vrijeme potrebno da se sise vrate u stanje prije mužnje znakovito je utjecao njihov položaj. Tako su se vrijednosti TWT-a, TCL-a i TD-a vratile u prvotno stanje 3 - 4 sata kod sisa smještenih na prednjoj lijevoj strani vimena. U sisama smještenim na stražnjoj lijevoj strani vimena samo se TWT vratio u prvotno stanje 4 sata nakon mužnje. Odstupanja su bila najveća odmah nakon mužnje, i to kod vrijednosti TD-a i TCD-a te jedan sat nakon mužnje u slučaju TCL-a i TWT-a. Zaključeno je da je u mliječnih krava križanki između holštajnsko-frizijske i sahival pasmine vrijeme od četiri sata nedovoljno za potpuno vraćanje sisa u stanje prije mužnje.

Ključne riječi: krave sahival; tkivo sisa; oporavak sisa, ultrazvuk; strojna mužnja

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