Artykuł przeglądowy *Review*

Ultrasound examination of mammary glands in ruminants

JAN OLECHNOWICZ, JĘDRZEJ M. JAŚKOWSKI

Department of Veterinary Medicine, Faculty of Breeding and Biology of Animals, University of Life Sciences in Poznań, Wojska Polskiego 52, 60-625 Poznań, Poland

Olechnowicz J., Jaśkowski J. M.

Ultrasound examination of mammary glands in ruminants

Summary

Machine milking of ruminants has a considerable effect on the length of the teat canal, the width of the teat sinus, the width of the teat end and the thickness of the teat wall. The width of the teat end and the length of the teat canal showed the biggest changes 6 and 2 h, respectively, after the completion of milking. The thickness of the teat wall and the width of the teat sinus returned to the original condition from before milking after 6 and 8 h, respectively. In sheep the thickness of the teat wall in left and right half-udders 4 h after milking increased by 17 and 16% in relation to measurements taken before milking, while for the length of the teat canal it was by 10 and 8%. With progress in lactation the area of milk sinuses in cows decreased significantly. Similarly, in Manchega and Lacune sheep the size of milk sinuses decreased during lactation. The values of correlation coefficients between the size of milk sinuses and milk yield of ewes, depending on the applied ultrasound measurement methods, were 0.53 and 0.48. The area of milk sinuses in goats and the daily milk production, irrespective of the number of milkings per day (one or two), increased linearly with the number of hours between milkings. In healthy mammary glands of cows teat canals were longer and narrower, while in infected glands they were shorter and wider. The length of the teat canal in cows was negatively correlated with the peak and mean values of the milk flow index.

Keywords: cows, small ruminants, ultrasound examination, teats, milk cistern

The condition of teats in ruminants is significantly affected by the ambient temperature and pathogenic microorganisms found in the environment in which the animals live (14), as well as milking, especially machine milking (12, 13, 15, 29). During hand milking and milk removal through a catheter placed in the teat canal minimal changes occur in the thickness of teat ends (9, 12). Similarly slight changes should accompany machine milking. According to Hamann and Mein (12), the thickness of teat ends after machine milking should not exceed 5%. A stronger teat swelling increases the risk of teat canal colonization by e.g. *Staphylococcus aureus* and indicates an increased milking vacuum (9, 31). Although a higher vacuum during machine milking results in an increased average flow rate (AFR), it may contribute to teat congestion and the swelling of teat ends (27). As a consequence, these changes may considerably reduce the resistance of teat canals to infection.

Ultrasonography has been applied to monitor teat response to machine milking in cows (6, 16, 19, 22) and recently also in sheep (6, 29). This method makes it also possible to assess changes in the cisternal size in cows and small ruminants during lactation (3, 18, 25, 28, 30). Owing to a significant relationship between the content of the secretory tissue in the mammary glands of heifers before calving and their later milk yields during 100-day lactation, this method has been applied to predict their yields (26). Ultrasonography is also used in the diagnostics of disturbances in milk flow as well as measurements and assessment of different anatomical structures of the udder and teats in ruminants (7, 19).

Three-dimensional ultrasonography has been applied in different areas of veterinary medicine. Using this technique, good-quality 3-D images have been obtained, for the first time presenting the mammary parenchyme, udder cisterns, teat cisterns, Furstenberg's rosettes and teat canals in the bovine mammary glands (7). The results of ultrasonographic examinations supply additional information on the condition of udders in cows and are useful in diagnostics. Striking similarities have been found between ultrasound images of diseased glands and those infested with certain pathogen species, especially *Arcanobacterium pyogenes* and Gram-negative organisms (5).

The aim of the study was to analyze the results of ultrasonographic examinations of mammary glands in

cows and small ruminants primarily in terms of machine milking, taking into consideration the effect of milking on the health status of mammary glands, as well as the peak flow rate (PFR) and average flow rate (AFR).

Physiological response of teats to machine milking

Factors related with machine milking and leading to external skin damage on udders and teats in cows were presented in detail in a previous study (21). In order to assess the effect of individual structures of the teat canal on the health status of the udder in cows, different methods of measuring the length and diameter of the teat canal were used, applying radiographic techniques (11) or sterile cannulas (17). At present ultrasonography is applied with increasing frequency (6, 9, 10, 16, 19). Measurements of the length and width of the teat end are taken as a standard procedure at the internal opening of the teat canal, while the thickness of the teat wall and the width of the teat cistern are assessed 1 cm over the internal opening of the teat canal. Additionally, the ratio of the teat wall thickness to the teat cistern width is calculated (9).

The mean length of the teat canal in Holstein cows before milking was 10 mm and increased to 11.2 mm after milking. The teat canal elongated during machine milking from 30 to 42%, with the variation in the length of the teat canal being considerably (in 80%) dependent on udder preparation. Changes in the width of teat ends were relatively slight in comparison to changes observed in the other sections of teats. The average width of teat ends increased from 21.2 mm before milking to 21.7 mm after milking. The thickness of the teat wall increased from 6.8 mm before milking to 9.1 mm after milking. The ratio of teat wall thickness to the width of the teat cistern before milking was 0.6 and increased to 1.2 immediately after milking; 6 h after milking, however, the difference turned out to be statistically non-significant (19).

Machine milking in cows in comparison to milk removal through a catheter results in increased diameter, length and thickness of the teat wall (10). Reduced teat wall thickness following hand milking and milk removal through a catheter in the opinion of the cited authors resulted from a reduced intramammary pressure or the displacement of systemic fluids to lower parts of the teat. As a consequence of a 30-second udder stimulation prior to milking the diameter of the teat cistern increased significantly, at the simultaneous reduction of the thickness of its wall and the length of the teat canal in comparison to teats which were not stimulated (10). At the same time no significant differences were found in the diameter of teat ends or their length. Milk production (6.4 and 17.8 kg/milking) had a significant effect on changes in the length of the teat canal, cistern diameter and teat wall thickness (before and after milking); however, no such effect was recorded in relation to the diameter of the teat ends (10). According to those authors, overmilking lasting for 5 and 8 minutes periodically reduced the diameter of the teat cistern. The diameter of teat ends and their length 1 h after milking were comparable to the values recorded after udder stimulation. The diameter of the teat cistern and the length of the teat canal did not return to the status after udder stimulation within 5 h. Machine milking in cows resulted in an increased teat diameter, while udder stimulation, milk production level and overmilking time did not have any effect on the diameter of teat ends.

In sheep (ewes of a milk line with an approx. 90% share of the genes of the East Friesian milk sheep in their genotype) teat wall thickness 4 h after milking increased (in relation to the respective parameters before milking) by 17 and 16%, respectively, while the length of the teat canal increased by 10 and 8%. The short-term effect of milking on teats was a gradually regressing swelling, visible on ultrasound images 10 h after milking. Teat swelling may lead to a reduced teat canal resistance to bacterial infection while teats return to their condition before milking (29).

Ultrasonographic measurements of cistern size

The area of the udder cistern and the amounts of cistern and alveolar milk in Holstein cows increased with an extension of milking interval. The values of correlation coefficients between the area of the udder cistern and the amount of cistern milk were positive, with the highest values being recorded at 8 h and 12 h intervals between milkings (1).

The values of correlation coefficients between the cisternal area and the amount of cistern milk in British Friesian cows decreased significantly from early (mean 56 days), through mid (mean 151 days) to late (mean 311 days) lactations. With progressing lactation the cisternal area was observed to decrease, with the same downward trend being recorded for the collected amounts of cistern and alveolar milk. In the early, mid and late lactation the percentage of cistern milk was on average 33, 23 and 43% total bulk milk (3). The cisternal area in cows both at long (16 h) and short (8 h) milking intervals increased significantly 3 min after the intravenous injection of 5 units of oxytocin. It increased by 136 and 60% at 8 h and 16 h milking intervals, respectively (3).

In Manchega and Lacune sheep at day 30, 60 and 105 of lactation significant differences were recorded in the size of milk sinuses depending on the breed (24). In ewes of both breeds a significantly positive correlation was observed between the cisternal size and the amounts of cistern milk. In East Friesian and Lacune ewes the cisternal size did not differ, although some cisterns below the teat canal openings were larger in East Friesian ewes than in Lacune ewes, amounting to 37 and 25% total cistern area (2).

The size of the cisternal area in Sarda breed ewes depends on the length and diameter of the cistern

measured in the widest section. The values of correlation coefficients between the cisternal area and these parameters in Sarda ewes were r = 0.79 and r = 0.78, respectively (20). In the study by the authors cited above high and significant values of correlation coefficients were recorded between the cisternal area and the amount of cistern milk as well as the total milk yield from a milking, which amounted to 0.82 and 0.81, respectively. Milk production in ewes depended to a considerable degree on the amount of cistern milk.

Using the results of ultrasound measurements, work on the improvement of morphological traits of the udder and milk recording in sheep of the Improved Valachian, Tsigai, Lacune and their crosses is conducted in Slovakia (18). Two methods were applied in the studies: placing the probe at the bottom of the udder (using water immersion) and in the peroneal position. The values of correlation coefficients between the established area and milk yield of ewes for both applied methods were r = 0.53 and r = 0.48. In milk recording of Polish White Improved goats the most suitable parameters were the width and cross-section area of cisterns (30). Higher values of correlation coefficients between the dimensions of cisterns and milk yield were recorded in 2- to 3-year-old goats than in older animals. The shape of the udder in goats had a significant effect on the clarity of ultrasound images. Images free from artefacts were obtained for goats with oval mammary glands.

The cisternal area in Murciano-Granadina goats milked once or twice a day did not differ at different milking intervals (8, 16 and 24 h). The cisternal size and daily milk production in goats milked once and twice daily increased with an extension of intervals between milkings. In multiparous animals cisterns and their capacity to keep milk were bigger than in primiparous ewes. Owing to the high capacity of cisterns in goats the elimination of one milking within 24 h did not result in milk returning to milk alveoli (25). In Polish White Improved goats the cisternal area was measured by four ultrasound methods using linear and sector probes of different frequencies (28). The smallest cisternal area was determined using a 3.5 MHz linear probe. The authors of the cited study recommended measuring the mammary cistern size with a 5 MHz linear probe because of the large operation area and a low probability of ultrasound image distortion during measurements.

Anatomical traits of teats vs. resistance to infection and milk flow characteristics

It follows from the available literature that the thickness of the teat wall in cows is positively correlated with the teat diameter (r = 0.41) and the length of the teat canal (r = 0.57) (27). In turn, no relationship was found between the length and diameter of teats and the length of the teat canal. The length of the teat canal was negatively correlated with the peak flow rate (PFR) (r = – 0.24) and the average flow rate (r = – 0.33) (27). The probability of udder quarter infection with *Streptococcus agalactiae* increased significantly with an increase in the peak value of milk flow rate (11, 17), whereas gland infections with *Streptococcus uberis* were correlated with a shortening of the teat canal (17).

The length and diameter of the teat canal were significantly different in healthy and infected udder quarters in Brown Swiss, pure-bred Simmental, Holstein-Friesians and Simmental crossed with Red Pied cows (16). Longer teat canals with smaller diameters were found in cows with healthy quarters of the udder. They were also recorded in healthy quarters of the udder in successive lactations of cows.

During milking, among other things, keratin produced by teat canal cells is washed out. Keratin loss constitutes a mechanical stimulus for the epithelium of the teat canal for it to be produced again. Reduced keratin loss, adhesion of bacteria to the epithelium of the teat canal and swelling of the teat end are additional factors increasing the probability of *mastitis* (4). The solids content of keratin obtained experimentally from the teat canal was significantly correlated with the length of the teat canal (23). The length of the teat canal in cows had an effect on the amount of contained keratin, although its recovery did not depend on the diameter of the teat canal. A higher percentage of infected glands was recorded in udder quarters with low amounts of keratin washed from teat canals (17).

The results of clinical studies assessing the teat condition in sheep were compared with those from ultrasound examinations (8). Selected parameters characterizing traits of the udder and teat canals were correlated with a positive result of the California Mastitis Test (CMT) and the response typical of subclinical and clinical forms of *mastitis*. Such results were recorded in most udder-halves whose teats were long (≥ 9 mm) or had wide (≥ 2.5 mm) teat canals (75% and 83%, respectively).

Recapitulation

Ultrasonography has been applied to monitor teat response to machine milking in ruminants. Correct preparation of the cow's udder to milking significantly decreases the extension of the teat canal during milking. Milk yield (6.4 kg vs. 17.8 kg per milking) had a significant effect on changes in the canal length, cistern diameter and teat wall thickness, but did not affect the teat diameter. Over-milking by five and eight minutes did not affect teat diameter, teat wall thickness or canal length values, but reduced cistern diameter values.

In sheep the teat wall thickness 4 h after milking increased (in relation to the respective parameters before milking) by 17 and 16%, respectively, while the length of the teat canal increased by 10 and 8%. The short-term effect of milking on teats was a gradually

regressing swelling, visible on ultrasound images 10 h after milking.

In ruminants the cisternal area increased with an extension of milking interval. With progressing lactation the cisternal area was observed to decrease.

The length of the teat canal in cows was negatively correlated with the peak flow rate and the average flow rate. The probability of udder quarter infection with *Streptococcus agalactiae* increased significantly with an increase in the peak value of milk flow rate. Gland infections with *Streptococcus uberis* were correlated with a shortening length of the teat canal. Selected parameters characterizing the traits of the udder and teat canals were correlated with a positive result of the California Mastitis Test and the response typical of subclinical and clinical forms of *mastitis*. Such results were recorded in most udder-halves whose teats were long or had wide teat canals.

References

1. *Ayadi M., Caja G., Such X., Knight Ch. H.*: Use of ultrasonography to estimate cistern size and milk storage at different milking intervals in the udder of dairy cows. J. Dairy Res. 2003, 70, 1-7.
2. *Bruckmaier R. M., Paul G., Mayer H., Schams D.*: Machine milking of Ostfriesian and Lacaune dairy sheep: udder anatomy, milk ejection and milking characteristics. J. Dairy Res. 1997, 64, 163-172.
3. *Caja G., Ayadi M., Knight Ch. H.*: Changes in cisternal compartment based on stage of lactation and time since milk ejection in the udder of dairy cows. J. Dairy Sci. 2004, 87, 2409-2415.
4. *Capuco A. V., Mein G. A., Nicerson S. C., Jack L. J. W., Wood D. L., Bright S. A., Aschenbrenner R. A., Miller R. H., Bitman J.*: Influence of pulsationless milking on teat canal keratin and mastitis. J. Dairy Sci. 1994, 77, 64-74.
5. *Flöck M., Winter P.*: Diagnostic ultrasonography with diseases of the mammary gland. Vet. J. 2006, 171, 314-321.
6. *Franz S., Baumgartner W., Hofmann-Parisot M., Windischybauer G., Suchy A., Bauder B.*: Ultrasonography of the teat canal in cows and sheep. Vet. Rec. 2001, 149, 109-112.
7. *Franz S., Hofmann-Parisot M., Baumgartner W.*: Evaluation of three-dimensional ultrasonography of the bovine mammary gland. Am. J. Vet. Res. 2004, 65, 1-5.
8. *Franz S., Hofmann-Parisot M., Gütler S., Baumgartner W.*: Clinical and ultrasonographic findings in the mammary gland of sheep. N. Z. Vet. J. 2003, 51, 238-243.
9. *Gleeson D. E., O'Callaghan E. J., Rath M. V.*: Effect of liner design, pulsator setting, and vacuum level on bovine teat changes and milking characteristics as measured by ultrasonography. Ir. Vet. J. 2004, 57, 289-296.
10. *Gleeson D. E., O'Callaghan E. J., Rath M. V.*: Effect of milking on bovine teat tissue as measured by ultrasonography. Ir. Vet. J. 2002, 55, 628-632.
11. *Grindal R. J., Walton A. W., Hillerton J. E.*: Influence of milk flow rate and streak canal length on new intramammary infection in dairy cows. J. Dairy Res. 1991, 58, 383-388.
12. *Hamann J., Mein G. A.*: Measurement of machine induced changes in the thickness of the bovine teat. J. Dairy Res. 1990, 57, 495-505.
13. *Hamann J., Mein G. A., Wetzel S.*: Teat tissue reactions to milking: effects of vacuum level. J. Dairy Sci. 1993, 76, 1040-1046.
14. *Hillerton J. E., Ohnstad I., Baines J. R., Leach K. A.*: Changes in cow teat tissue created by two types of milking cluster. J. Dairy Res. 2000, 67, 309-317.
15. *Hillerton J. E., Pankey J. W., Pankey P.*: Effect of over-milking on teat condition. J. Dairy Res. 2002, 69, 81-84.
16. *Klein D., Flöck M., Khol J. L., Franz S., Stüger H. P., Baumgartner W.*: Ultrasonographic measurement of the bovine teat: breed differences, and the significance of the measurements for udder health. J. Dairy Res. 2005, 72, 296-302.
17. *Lacy-Hulbert S. J., Hillerton J. E.*: Physical characteristics of the bovine teat canal and their influence on susceptibility to streptococcal infection. J. Dairy Res. 1995, 62, 395-404.
18. *Milerski M., Margetin M., Apolen D., Capistrak A., Spanik J.*: Udder cistern size and milkability of ewes of various genotypes. ICAR Techn. 2005, Ser 10, 63-69.
19. *Neijenhuis F., Klungel G. H., Hogeveen H.*: Recovery of cow teats after milking as determined by ultrasonographic scanning. J. Dairy Sci. 2001, 84, 2599-2606.
20. *Nudda A., Pulina G., Vallebella R., Bencini R., Enne G.*: Ultrasound technique for measuring mammary cistern size of dairy ewes. J. Dairy Res. 2000, 67, 101-106.
21. *Olechnowicz J.*: Zewnętrzne i wewnętrzne uszkodzenia strzyków krów (External and internal damage to teats in cows). Medycyna Wet. 2007, 63, 786-791 (in Polish).
22. *Paulrud C. O., Clausen S., Andersen P. E., Rasmussen M. D.*: Infrared thermography and ultrasonography to indirectly monitor the influence of liner type and overmilking on teat tissue recovery. Acta Vet. Scand. 2005, 46, 137-147.
23. *Paulrud C. O., Rasmussen M. D.*: How teat canal keratin depends on the length and diameter of the teat canal in dairy cows. J. Dairy Res. 2004, 71, 253-255.
24. *Rovai M., Such X., Caja G., Piedrafita J.*: Change in cisternal and alveolar milk throughout lactation in dairy sheep. J. Dairy Sci. 2002, 85 (Suppl 1) (Abstr.), 4.
25. *Salama A. A. K., Caja G., Such X., Peris S., Sorensen A., Knight Ch. H.*: Changes in cisternal udder compartment inducted by milking interval in dairy goats milked once or twice daily. J. Dairy Sci. 2004, 87, 1181-1187.
26. *Strzetelski J. A., Bilik K., Niwińska B., Skrzyński G., Łuczyńska E., Choroszy Z.*: Przydatność ultrasonograficznego badania gruczołu mlekowego jałówek do prognozowania ich wydajności mlecznej (Suitability of ultrasonographic examination of the mammary glands in heifers to predict their milk yield). Medycyna Wet. 2005, 61, 1032-1035 (in Polish).
27. *Weiss D., Weinfurtner M., Bruckmaier R. M.*: Teat anatomy and its relationship with quarter and udder milk flow characteristics in dairy cows. J. Dairy Sci. 2004, 87, 3280-3289.
28. *Wójtowski J., Ślósarz P., Bielińska S., Nowicki S., Gut A., Danków R.*: Ultrasound image of morphological changes of teat end in sheep caused by machine milking. Arch. Tierz. Dummerstorf 2006, 49, 231-237.
29. *Wójtowski J., Ślósarz P., Jankuszew A., Milerski M., Szymanowska A., Szymanowski M.*: Application of ultrasound technique for cystern size measurement in dairy goats. Arch. Tierz. Dummerstorf 2006, 49, 382-388.
30. *Wójtowski J., Ślósarz, P., Malecha W., Danków R.*: Ultrasonograficzne pomiary zatoki mlekonośnej wymienia kóz podczas laktacji (Ultrasonographic measurements of milk sinus in the udder of goats during lactation). Medycyna Wet. 2002, 58, 977-980 (in Polish).
31. *Zecconi A., Hamann J., Bronzo V., Ruffo G.*: Machine-induced teat tissue reactions and infection risk in a dairy herd free of contagious mastitis pathogens. J. Dairy Res. 1992, 59, 265-271.

Author's address: dr hab. Jan Olechnowicz, Osiedle Wichrowe Wzgórze 13/93, 61-675 Poznań; e-mail: olejanko@up.poznan.pl