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Full Length Research Paper

Machine induced changes of caprine teats diagnosed by ultrasonography

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Analyses were performed on 10 nanny goats of the Polish White Improved breed aged 2 to 5 years. Ultrasound images of the longitudinal cross-section of teats were taken in 9 replications, 4 times daily before and immediately after morning milking, and then 4 and 10 h after milking, using a Hitachi EUB405+ apparatus with a 10 MHz linear probe. The ultrasound probe was placed in a plastic cup filled with water (approximately 30 - 35°C), in which teats were immersed. Measurements of the diameter and length of the teat canals and the thickness of the teat wall were taken on ultrasound images in the MultiScan® 12.05. computer software. Immediately after milking a marked thickening (swelling) of the teat wall, an elongation of the teat canal was observed by approximately 40 and 18%, respectively ($p < 0.01$). Four hours after milking, the swelling was still considerable and teat walls were thicker by approximately 30% ($p < 0.01$). These changes started to subside after approximately 10 h after milking, at that time reaching a level close to the initial condition, which may indicate the necessity to provide animals with an approximately 10 to 12 h intervals between milkings to ensure teat regeneration. Less marked changes in teat morphology is concerned with the measurement of the diameter of the teat canal. No definite effect of age of animals (lactation) and the shape of the udder on teat morphology were observed. Results of analyses indicate considerable suitability of ultrasonography in the monitoring of caprine teat morphology; however, thorough training of operators is required, since significant differences were observed in values of individual measurements between operators with varying professional experience.

Key words: Goat, teat reaction, machine milking, ultrasonography.

INTRODUCTION

Teats of milked farm animals are parts of the udder, serving the role of both a valve regulating milk outflow as well as that of a natural barrier for exogenous infections, affecting the quality traits of milk (Skrzypek et al., 2003). Advances in the ultrasound technique observed in the last decade facilitate an increasingly precise examination of morphology of caprine mammary glands with the application of this method (Wójtowski et al., 2002; Wójtowski et al., 2006b). Studies on teat reaction to machine milking conducted using ultrasound equipment have been performed primarily on dairy cattle (Neijenhuis et al., 2000; Franz et al., 2001a), and only to a considerably smaller degree on small ruminants (Franz et al., 2001b; Wójtowski et al., 2006a). In scarce studies conduced on goats, periodical changes in teat structures caused by milking were typically evaluated based on only one measurement taken after milking (Fahr et al., 2001). This prevented a comprehensive evaluation of the dynamics of changes occurring in teats in the period preceding the following milking and indication of an optimal interval between milkings. The aim of this study was to evaluate morphological changes in caprine teats in response to the performed machine milking, taking into consideration three post-milking time intervals. Additionally, it was also decided to verify the accuracy of

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performed measurements taken by two operators differing in terms of their experience and expertise.

MATERIALS AND METHODS

Analyses were conducted on 10 nanny goats of the Polish White Improved breed aged 2 to 5 years (the 1st to 4th lactation), kept at the Zlotniki Experimental Station, belonging to the Poznań University of Life Sciences. In the period of analysis, goats were in their 5th and 6th months of lactation and the mean milk yield of examined animals at the time of the experiment was approximately 2.5 kg. Goats were milked in a 10-unit milking parlour equipped with milking clusters for goats with pulse frequency of 90 ± 5 pulses per minute and a milking vacuum of 44 kPa.

Udder types in goats were classified based on previously taken zoometric measurements of udders. Pear-shaped udders (elongated udders with a narrow attachment) or box-like udders (elongated udders with a wide attachment) in which width was markedly smaller than their height were classified as oval (pendulous) udders. Udders in which outer shape resembled a sphere and their width was equal to or bigger than their height were classified as round udders.

Ultrasound images of the longitudinal cross-section of both teats were obtained using a Hitachi EUB 405+ apparatus with a 10 MHz linear probe on animals immobilized in milking units. The ultrasound probe was placed in a plastic cup filled with water at a temperature of approximately 30 to- 35°C, in which teats were immersed. Images were recorded in real time on VHS cassettes and next transmitted via a INDEO® Fast Frame Grabber card to a computer and recorded in the form of disc files (a bit map). Ultrasound measurements were taken four times daily at the following time intervals: before morning milking, immediately after morning milking, 4 h after morning milking and 10 h after morning milking (immediately before evening milking). A total of 9 replications were made of the described experiment, yielding jointly 720 teat images. On recorded images, in the MultiScan® 12.05 computer system (Computer Scanning Systems Ltd.), the diameter and length of the teat canal and the thickness of the teat wall were measured at the height of Fürstenberg's rosette. All measurements in this part of the experiment were taken by the same individual (operator no. 1) with considerable experience in the evaluation of ultrasound images. Additionally, in order to evaluate the effect of the operator on the accuracy of recorded results, teat measurements were repeated by another person (operator no. 2), with a much more limited experience in this respect.

The effect of the time interval between measurements (1,...4), replications of the experiment (1,...9), lactation rank (1,...3) and the type of the udder (1, 2) on teat morphology was estimated using a multivariate analysis of variance (SAS 9.1.), based on measurements taken by operator no. 1 (the more experienced one). Moreover, an additional analysis of variance was performed according to the above mentioned model, which assumed that the data were the difference in values between individual measurements taken by operators 2 and 1, and as such, made it possible for the variation in the interpretation of ultrasound images by both operators to be evaluated.

RESULTS

The effect of experimental factors on parameters of caprine teat morphological structure is presented in Table 1. Immediately after milking, a thickening of teat walls by approximately 43 and 37%, respectively, was observed in relation to the left and right teat ($p < 0.01$). Four hours after milking, the swelling was still considerable and teat walls were thicker by approximately 30% ($p < 0.01$). This phenomenon is clearly visible on the examples of teat ultrasound images of one examined goat (Figure 1 a, b, c, d, e and f). As late as 10 h after milking, swelling of teat walls was markedly reduced, although it still amounted to 8 to 11% in relation to the original condition ($p < 0.01$; Figure 1 g and h). A similar, although a slightly less intensive effect of machine milking was observed also in relation to the measurement of teat canal length. Immediately after milking, the length of the teat canal was by approximately 18% bigger than before milking ($p < 0.01$) and this dimension was close to the initial condition only after as many as 10 h after the completion of milking ($p > 0.05$). Less marked changes in teat morphology under the influence of milking was concerned with the measure-ment of the diameter of the teat canal and they were confirmed statistically only in relation to the left teat. The biggest opening of the teat canal was observed immediately after milking, while after 10 h from the completion of milking, this dimension was even slightly smaller than before milking ($p > 0.05$).

In relation to most analyzed traits, no statistically significant effect of age of animals (lactation) on teat morphology was observed; however, usually individual measurements in the youngest goats had slightly lower values. Moreover, no definite effect of the shape of the udder on teat morphology was found, apart from a bigger length of the left teat canal and a smaller thickness of the wall in the right teat in goats with oval udders ($p < 0.05$). In contrast, the variation of teat measurement results proved to be significant in individual replications of the experiments.

Table 2 presents mean results of teat measurements taken in the same ultrasound images, independently by 2 operators. In case of measurements of the left teat, operator no. 2 (the less experienced one) clearly overstated measurements of teat thickness ($p < 0.01$), at the same time underestimating measurements of the length and diameter of teat canals. These described definite trends concerned also the right teat and they were confirmed statistically in case of measurements of the length and diameter of teat canals. Differences in the evaluation of teat morphology recorded by both operators, and as a consequence in the accuracy of their measurements, were particularly evident depending on the date of the measurements (Table 3). In the case of both teats, operator no. 2 typically overstated the measurement of the teat wall thickness; however, at measurements taken immediately after milking, the measurement of this operator was underestimated, as evidenced by the negative value of the difference between the measurement of operators 2 and 1 ($p < 0.01$). In turn, the measurement of the length of the teat canal was underestimated by operator 2 to an identical degree, irrespective of the date of the measurement. The less

Table 1. Results of ultrasound teat measurements in goats.

Factor	n	Left teat [mm]			Right teat [mm]		
		Wall thickness	Canal length	Canal diameter	Wall thickness	Canal length	Canal diameter
Measurement (M):		**	**	*	**	**	ns
- before milking	90	4.68±0.16 ABa	8.57±0.23 AB	0.92±0.03 a	5.00±0.19 ABC	8.57±0.23 AB	0.92±0.04
- immediately after milking	90	6.71±0.18 ACb	10.11±0.26 AC	0.99±0.04 ABa	6.83±0.21 ADE	10.21±0.27 AC	0.95±0.04
- 4 h after milking	90	6.29±0.16 BDb	9.71±0.23 Ba	0.86±0.03 A	6.32±0.18 BDF	9.87±0.24 BD	0.95±0.04
- 10 h after milking	90	5.02±0.17 CDa	9.04±0.24 Ca	0.88±0.03 B	5.66±0.18 CEF	8.92±0.24 CD	0.87±0.04
Lactation (L):		**	ns	ns	ns	ns	ns
1	72	5.17±0.16 Aa	9.20±0.23	0.87±0.03	5.98±0.18	9.26±0.22	0.92±0.04
2	180	5.82±0.13 A	9.41±0.21	0.91±0.03	5.83±0.17	9.58±0.21	0.92±0.03
≥ 3	108	5.74±0.14 a	9.22±0.22	0.95±0.03	6.07±0.19	9.52±0.24	0.94±0.04
Type of udder (T):		ns	*	ns	*	ns	ns
- round	180	5.70±0.14	9.19±0.19	0.91±0.03	6.16±0.16	9.38±0.20	0.91±0.04
- oval (pendulous)	180	5.68±0.12	9.57±0.17	0.92±0.02	5.78±0.15	9.60±0.21	0.93±0.04
Replication (R):		**	**	**	**	**	**
Interactions		MxL**	MxT*	ns	MxT**	ns	ns

A,B… (a,b…), means denoted with identical capital (small) letters differ significantly at P ≤ 0.01 (P ≤ 0.05); **, P ≤ 0.01; *, P ≤ 0.05; ns, difference statistically non-significant.

experienced operator underestimated also the measurement of the diameter of both teat canals, with the biggest error being made at the measurement of the left teat before the morning milking ($p < 0.01$). A certain variation in the accuracy of measurements was also found depending on the type of udder structure. However, it needs to be stressed that both in the case of the left and the right teat, no effect was observed for the replication of the examination and lactation (age) of nanny goats on differences between measurements taken by both operators. This means that factors not affecting directly teat morphology have no effect on the accuracy of measurements.

DISCUSSION

Morphology of the mammary gland is a key factor for the optimization of machine milking parameters of small ruminants (Rovai et al., 2008). Short-term changes within the teat caused by milking most frequently was concerned with the colour, swelling and opening of the teat canal and they may remain up to 6 to 8 h after milking, becoming the cause of udder inflammation (Neijenhuis et al., 2000). In the cited studies, a considerable swelling of teat walls was found in cattle after milking (26 to 50%) as well as an elongation of the teat canal (19 to 28%). A similar intensity of changes in teat wall thickness and the length of the teat canal in nanny goats (30 and 20%, respectively) after 1 h after milking was reported by Fahr et al. (2001). Results recorded in this study generally fell within the above mentioned limits; however, morphological changes, particularly teat swelling, were retained for a longer time and as late as 10 h after milking, they were 8 to 11% in relation to the initial condition ($p < 0.01$). Thickening of the teat wall in examined goats, despite the passage of time, was thus bigger than that considered natural in case of properly performed machine milking in cattle (Hamman et al., 1996). It needs to be indicated that in methodologically similar studies conducted earlier by the same team in sheep (Wójtowski et

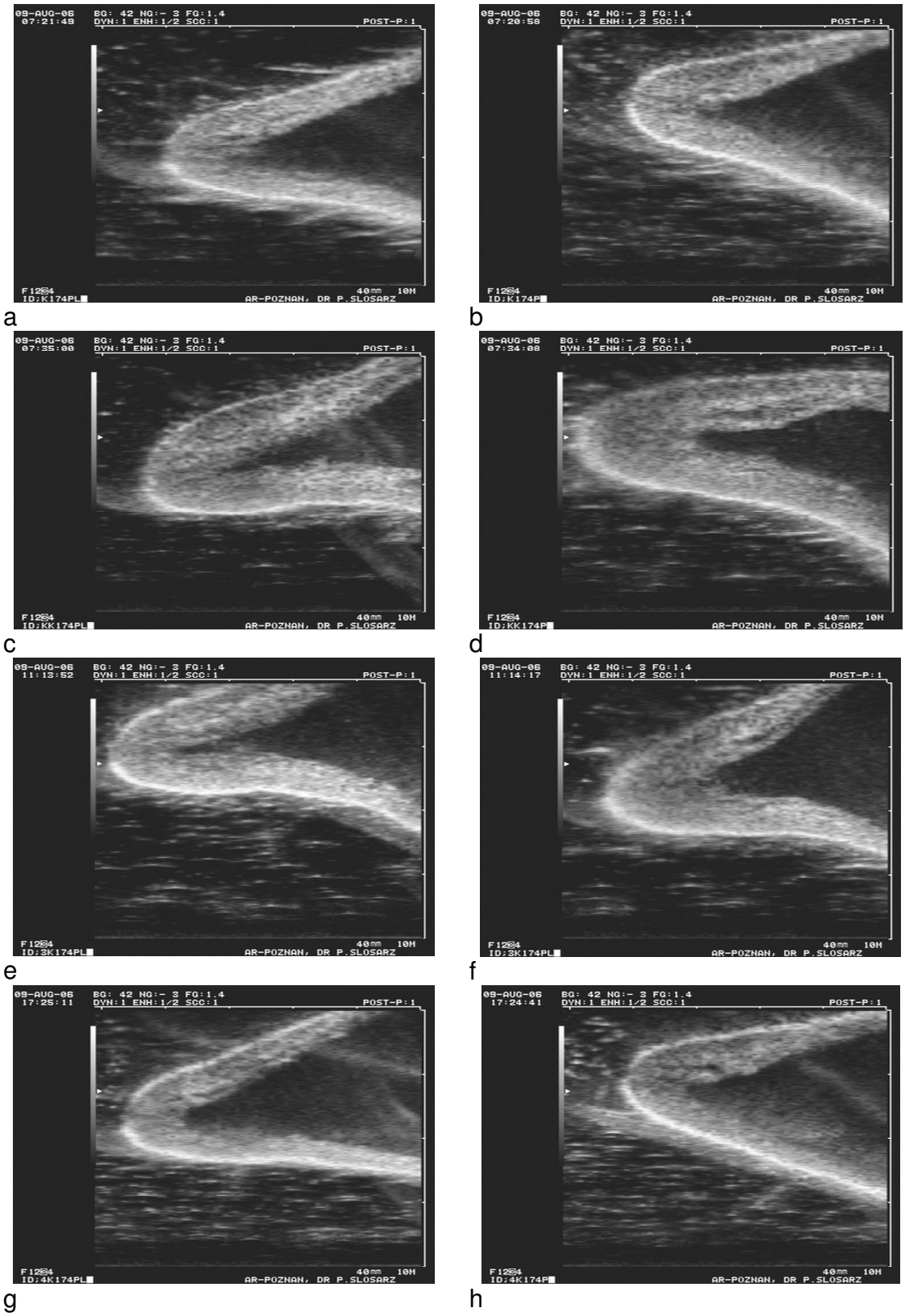

Figure 1. a, b, Left and right teat of goat no. 174 before morning milking; c, d, left and right teat immediately after morning milking; e, f, left and right teat 4 h after milking; g, h, left and right teat 10 h after milking (a Hitachi EUB 405B scanner with 10MHz linear probe). Photo by P. Ślósarz.

Table 2. Results of ultrasound teat measurements in goats performed by two operators.

Factor	Left teat (mm)			Right teat (mm)		
	Wall thickness	Canal length	Canal diameter	Wall thickness	Canal length	Canal diameter
Operator	**	*	**	ns	*	**
1	5.71±0.10	9.21±0.22	0.91±0.02	5.96±0.15	9.40±0.23	0.91±0.02
2	6.43±0.11	8.41±0.23	0.70±0.02	6.10±0.15	8.61±0.23	0.72±0.02

**, P ≤ 0.01; *, P ≤ 0.05; ns, difference statistically non-significant.

Table 3. Effect of operator on ultrasound teat measurements – expressed as the difference between the measurements performed by 2nd and 1st operator.

Factor	Left teat [mm]			Right teat [mm]		
	Wall thickness	Canal length	Canal diameter	Wall thickness	Canal length	Canal diameter
Measurement (M):	**	ns	**	**	ns	ns
- before milking	1.33±0.25Aa	-0.88±0.51	-0.31±0.04 AB	0.13±0.33 a	-0.99±0.51	-0.14±0.04
-immediately after milking	-0.49±0.31 ABC	-1.04±0.63	-0.23±0.06	-0.91±0.36 aAB	-0.43±0.55	-0.19±0.05
- 4 h after milking	0.59±0.25 aB	-0.26±0.50	-0.14±0.05 A	0.41±0.33 A	-1.10±0.51	-0.19±0.05
- 10 h after milking	1.28±0.25 C	-0.90±0.51	-0.14±0.05 B	0.92±0.34 B	-0.50±0.51	-0.24±0.05
Lactation (L):	ns	ns	ns	ns	ns	ns
1	0.40±0.29	-1.79±0.58	-0.27±0.05	-0.26±0.39	-0.73±0.59	-0.26±0.05
2	0.46±0.15	-0.70±0.31	-0.21±0.03	0.25±0.21	-0.88±0.32	-0.19±0.03
≥ 3	1.17±0.32	-0.04±0.65	-0.15±0.06	0.21±0.29	-0.65±0.60	-0.12±0.06
Type of udder (T):	**	*	ns	ns	ns	ns
- round	1.15±0.19	-0.14±0.38	-0.17±0.03	0.12±0.25	-0.61±0.38	-0.16±0.03
- oval	0.20±0.21	-1.40±0.46	-0.24±0.04	0.14±0.29	-0.90±0.45	-0.23±0.04
Replication (R):	ns	ns	ns	ns	ns	ns

A,B… (a,b…), means denoted with identical capital (small) letters differ significantly at P ≤ 0.01 (P ≤ 0.05); **, P ≤ 0.01; *, P ≤ 0.05; ns, difference statistically non-significant.

al., 2006a), morphological changes in teats under the influence of milking were less intensive and disappeared before the passage of 10 h after milking. Results obtained in this study may thus indicate the necessity of further studies on the optimization of milking parameters in goats. A strict dependence of the intensity of changes in teat wall thickness on parameters of the milking machines, including vacuum values, was shown, e.g. in a study by Sinapis et al. (2006).

Conducted analyses indicate a slightly different course of teat regeneration in goats after milking in comparison to dairy cattle. In this study, the elongation of teat canals after milking was less intensive and lasted shorter than the thickening of the teat wall. In contrast, in cattle, the length of the teat canal returned to the condition before milking as late as after 5 h, while the thickening of the teat wall lasted only approximately 1 h (Gleeson et al., 2002).

Results of conducted analyses indicate high

suitability of ultrasonography in the analysis of teat morphology and a high precision of measurements, demonstrated by the lack of the effect of replications of examinations on the accuracy of measurements made by two operators. This shows that both operators, separately in each of the successive days of analysis, were consistently and similarly evaluated in teat morphology of a given nanny goat. However, it is necessary to provide thorough training for the personnel taking ultrasound measure-ments, since significant differences were found in values of individual measurements between operators varying in experience.

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