Short communication: Effects of milk removal on teat tissue and recovery in Murciano-Granadina goats

M. Alejandro, A. Roca, G. Romero, and J. R. Díaz¹

Departamento de Tecnología Agroalimentaria, Escuela Politécnica Superior de Orihuela, Universidad Miguel Hernández, 03312 Orihuela, Alicante, Spain

ABSTRACT

The aim of this work was to study how machine milking (MM) carried out in appropriate conditions affects teat wall thickness and canal length and their return after milking to premilking conditions compared with other milk removal methods considered biological referents: kid suckling (KS), catheter removal (CATH), and hand milking (HM). Three Latin square experiments were designed, each divided into 2 periods. In the first period, the left glands of each animal were machine milked and the KS, CATH, and HM treatments were applied to the right glands in experiments 1, 2, and 3, respectively. Subsequently, in the second period, the removal methods were interchanged. Teat wall thickness, teat wall area, teat end wall area, and teat canal length were measured from the ultrasound images. Milk removal using the reference methods (KS, CATH, and HM) and by MM caused increases in teat wall thickness and teat canal length, which were greater with MM. The time needed for the teat walls and canal to return to their physiological conditions before milk removal was greater than 10 h in the reference methods and following machine milking.

Key words: goat, teat recovery, congestion, ultrasonography, machine milking

Short Communication

The mechanical forces applied to the teat during milking cause physiological changes in the teat tissues that may affect teat recovery time or its return to premilking physiology before milking (Neijenhuis et al., 2001). According to Hamann and Osteras (1994), the recovery time for teat tissue after calf suckling provides a biological reference to evaluate how teat tissue reacts to machine milking.

It is important to establish teat recovery time in order to determine the minimum interval between milkings. If one milking interval is insufficient for teat

tissue recovery, the circulatory changes in the teat tissues cannot return to their normal physiological status (Hamann and Osteras, 1994), which may result in irreversible chronic changes following the application of a frequent milking regimen (Hamann and Osteras, 1994; Neijenhuis et al., 2001). Recovery time depends on the milking system used (Hamann and Mein, 1990; Gleeson et al., 2002), as well as the liner compression (Spanu et al., 2008) and liner type (Paulrud et al., 2005). In small ruminants, teat wall thickness recovery time after conventional machine milking can exceed 10 h (Ślósarz et al., 2010; goats) and ranges from 4 to 10 h (Wójtowski et al., 2006; sheep).

Due to the scarce information available on the effect of different milk removal methods on teat status and recovery time in goats, the aim of this work was to study how machine milking (MM) affects teat wall thickness and teat canal length and their recovery following milking in normal physiological conditions compared with other milk removal methods considered referents: kid suckling (KS), milk removal by catheter (CATH), and hand milking (HM).

To achieve the objectives, 3 experiments with a Latin square design were carried out, using 12 goats in the first experiment (KS), 11 in the second (CATH), and 12 in the third (HM). Every experimental phase included 2 periods. In the first experimental period, the left gland of each goat was machine milked, whereas in the right gland the milk was removed by kid suckling (experiment 1), catheter (experiment 2), or hand (experiment 3). In the second experimental period, the gland group treatments (left and right) were interchanged. Each experimental period included 2 sampling days at the end. On these sampling days, ultrasound examinations were performed before milk removal (B), after removal (A), and at 1, 2, 3, 4, 6, 8, and 10 h after milk removal. The milking units used had teatcups with automatic vacuum shut-off valves and silicone liners (Top Flow Z; GEA Farm Technologies, Bönen, Germany). The milking parameters used were 40 kPa vacuum level, 90 pulsations/min, and 60% pulsation ratio.

Ultrasound scanning of the 2 glands followed the methodology described by Díaz et al. (2013). A por-

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¹Corresponding author: jr.diaz@umh.es

table ultrasound unit (Agroscan AL, ECM, Noveko International Inc., Angoulême, France) was used, equipped with a 5-MHz linear probe. For the examination, a transparent plastic recipient filled with water at 37°C was used. The probe was placed inside a latex bag filled with contact gel and contact gel was applied between the latex bag and the recipient. The images obtained were processed using a software program designed for the purpose by the research team (Ecoteat) and the following measurements were studied: teat wall thickness (**TWT**, mean value of the 2 walls examined, cm), area of the teat walls (**TWA**, cm²), teat end wall area (**TEWA**, cm²), and teat canal length (**TCL**, cm).

The association between the explanatory variables and teat tissue variables was assessed using a stepwise linear mixed model procedure (Proc Mixed of SAS software version 9.1; SAS Institute Inc., Cary, NC). Teat wall thickness, TWA, TEWA, and TCL measured before and after milking and their increments were included as outcome variables and the following as explanatory variables (model 1): treatment (2 levels, 1 = kid, catheter, or hand milking, depending on the experiment carried out; 2 = machine milking), period (2 levels, 1: first period; 2: second period), day nested in period (2 levels, 1: first day; 2: second day), and the interaction of period and treatment. Goat and gland (2 levels: right, left) nested in goat were considered as random terms. The model considered was

$$Y_{ijklmn} = \mu + \alpha_i + \beta_j + \gamma_k(\delta_l) + \alpha\beta_{ij} + \kappa_m(\varepsilon_n) + \varepsilon_n + e_{ijklmn}, \quad [1]$$

where Y_{ijklmn} is the dependent variable; μ is the mean; α_i is the effect of the i th treatment (reference method of each experiment or MM); β_j is the effect of the j th period (first or second); $\gamma_k(\delta_l)$ is the effect of the k th experiment day (first or second) nested in the l th period (first or second); $\alpha\beta_{ij}$ is the interaction between treatment and period; $\kappa_m(\varepsilon_n)$ is the random effect of the m th gland (left or right) nested in the n th goat; ε_n is the random effect of the goat; and e_{ijklmn} is the residual error.

A similar modeling procedure was used to assess teat recovery in each of the treatments assayed in each experiment. As a result, the final model included TWT, TWA, TEWA, and TCL as the outcome variables and the following explanatory variables (model 2): moment (9 levels, -1 = before, 0 = after, 1, 2, 3, 4, 6, 8, and 10 h after milking); period (2 levels, 1: first period and 2: second period), and day nested in period (2 levels, 1: first day; 2: second day). Goat and gland nested in goat were considered as random terms. The model considered was

$$Y_{ijklmn} = \mu + \alpha_i + \beta_j + \gamma_k(\delta_l) + \kappa_m(\varepsilon_n) + \varepsilon_n + e_{ijklmn}, \quad [2]$$

where Y_{ijklmn} is the dependent variable; μ is the mean; α_i is the effect of the i th moment (-1, 0, 1, 2, 3, 4, 6, 8, 10 h); β_j is the effect of the j th period (first or second); $\gamma_k(\delta_l)$ is the effect of the k th experiment day (first or second) nested in the l th period (first or second); $\kappa_m(\varepsilon_n)$ is the random effect of the m th gland (left or right) nested in the n th goat; ε_n is the random effect of the goat; and e_{ijklmn} is the residual error. Milk yield and milking time were not included as covariables in the final model because they had no significant effect.

Table 1 shows the value of the variables measured by ultrasound (TWT, TWA, TEWA, and TCL) before and after milking and their increments in each experiment. In experiment 1 (KS), MM caused a significant increase after milking in TWT, TWA, and TEWA ($P < 0.001$) compared with KS, which resulted in an increment of the same variables. However, milk removal method had no effect on TCL. In experiment 2 (CATH), MM caused an increase in TWT, TWA, and TEWA ($P < 0.05$) compared with CATH, although the increment in TWT was unaffected by treatment. The increase in TWA and TEWA was smaller with CATH compared with MM, and TCL was not affected by the milk removal method. In experiment 3 (HM), MM caused a significant increase after milking in TWT, TWA, and TCL, and in the corresponding increments of the same variables, compared with HM.

The recovery time for all tested variables to return to premilking conditions was >10 h in all treatments assayed in the 3 experiments. We observed that teats included in MM batches and the reference removal methods showed no significant differences in any variable before milk removal. The recovery time of the variables after MM was not significantly different compared with that of the same variables after KS, CATH, and HM. However, we did observe an effect of removal method on the recovery pattern. Teat wall thickness was not decreased, compared with the value observed after milking, until 4 or 8 h after removal with CATH and KS, respectively. In experiment 3, the results obtained by MM were similar to those observed in the other experiments: TWT increased after milking (time = 0) and decreased in the remaining times after milking, although a different result was recorded for HM, where values continued to increase after milking for up to 2 h (Figure 1). Teat wall area, TEWA, and TCL had a similar pattern (data not shown).

Milk removal by KS caused a smaller increase in TWT compared with MM. This result is in concordance with that reported in cows by Hamann and Mein (1988), where machine milking caused greater teat wall

Table 1. Effects of milk removal methods in teat wall thickness (TWT), teat wall area (TEWA), and teat canal length (TCL) estimated by ultrasonography¹

Item	Experiment 1				Experiment 2				Experiment 3			
	KS	MM	Significance	CATH	MM	Significance	HM	MM	Significance	MM	Significance	
Before removal												
TWT, cm	0.37 ± 0.01	0.38 ± 0.01	NS	0.36 ± 0.01	0.37 ± 0.01	NS	0.35 ± 0.01	0.35 ± 0.01	NS	0.35 ± 0.01	NS	
TWA, cm ²	0.79 ± 0.02	0.79 ± 0.02	NS	0.77 ± 0.02	0.75 ± 0.02	NS	0.76 ± 0.01	0.76 ± 0.01	NS	0.76 ± 0.01	NS	
TEWA, cm ²	0.59 ± 0.03	0.61 ± 0.03	NS	0.58 ± 0.03	0.54 ± 0.03	NS	0.58 ± 0.02	0.57 ± 0.02	NS	0.57 ± 0.02	NS	
TCL, cm	0.61 ± 0.02	0.63 ± 0.02	NS	0.64 ± 0.02	0.61 ± 0.02	NS	0.63 ± 0.02	0.62 ± 0.02	NS	0.62 ± 0.02	NS	
After removal												
TWT, cm	0.50 ± 0.01	0.56 ± 0.01	***	0.48 ± 0.02	0.52 ± 0.02	***	0.47 ± 0.01	0.55 ± 0.01	***	0.55 ± 0.01	***	
TWA, cm ²	0.90 ± 0.02	0.99 ± 0.02	***	0.86 ± 0.02	0.92 ± 0.02	***	0.85 ± 0.02	0.96 ± 0.02	***	0.96 ± 0.02	***	
TEWA, cm ²	0.77 ± 0.03	0.88 ± 0.03	***	0.72 ± 0.03	0.79 ± 0.03	*	0.67 ± 0.02	0.86 ± 0.02	***	0.86 ± 0.02	***	
TCL, cm	0.78 ± 0.02	0.81 ± 0.02	NS	0.77 ± 0.02	0.78 ± 0.0	NS	0.72 ± 0.02	0.83 ± 0.02	***	0.83 ± 0.02	***	
Increment, %												
TWT	39.41 ± 3.55	52.53 ± 3.55	**	36.83 ± 5.55	44.26 ± 5.55	NS	37.61 ± 4.37	60.50 ± 4.37	***	60.50 ± 4.37	***	
TWA	15.61 ± 2.18	26.05 ± 2.18	***	14.06 ± 2.66	23.61 ± 2.66	**	12.04 ± 2.03	26.97 ± 2.03	***	26.97 ± 2.03	***	
TEWA	36.98 ± 5.75	52.31 ± 5.75	*	34.91 ± 5.90	55.01 ± 5.90	**	20.72 ± 5.69	59.31 ± 5.69	***	59.31 ± 5.69	***	
TCL	32.23 ± 4.33	29.52 ± 4.33	NS	26.36 ± 4.56	32.71 ± 4.56	NS	15.99 ± 4.00	38.44 ± 4.00	***	38.44 ± 4.00	***	

¹Values are means ± SEM; comparison of teat traits between kid suckling (KS) and machine milking (MM), between catheter removal (CATH) and MM, and between hand milking (HM) and MM.

P* < 0.05; *P* < 0.01; ****P* < 0.001.

Figure 1. Recovery time of teat wall depends on milk removal method. (a) Experiment 1: kid suckling (□) versus machine milking (▲); (b) experiment 2: removal by catheter (□) versus machine milking (▲); (c) experiment 3: hand milking (□) versus machine milking (▲). B = before milking; A = after milking.

thickness values, measured by cutimeter, than did calf suckling. In the current work, we observed that TWA and TEWA were lower with KS compared with MM. Although there are no published works on the effect of KS, the greater increase in the variables with MM may be due to differences in the forces exerted on the teat and in the duration of teat end exposure to the vacuum, as occurs in cows.

Teat wall thickness and TWA values after MM were greater than those with CATH. Moreover, the incre-

ments of TWA and TEWA were greater with MM compared with CATH. Gleeson et al. (2002), in cows, also found a higher TWT with MM compared with catheter removal. Those authors also reported a greater TCL with MM; in the current work, we found no differences in TCL between MM and CATH. When milk is removed by catheter, no vacuum is applied and no compression force is exerted on the teat, so TWT after milk removal by CATH would not be expected to vary compared with the premilking value. Despite this, we observed that TWT did increase, as in KS, although to a lesser extent than with MM. This coincides with results in bovines by Gleeson et al. (2002), who explained that because no pressure was exerted on the teat during ultrasound scanning, the results could be influenced by intramammary pressure. In this sense, Gleeson et al. (2002) indicated that, in cattle, teat thickness after milk removal by CATH and by HM is lower than that after machine milking because the intramammary pressure is reduced and the liquids in the teat end are redistributed.

The lowest increments in TWA, TEWA, and TCL recorded were obtained by HM (Table 1). These results agree with those reported by Gleeson et al. (2002) in bovines. In hand milking, no vacuum is applied to the teat, although forces are exerted on the teat cistern to raise the intracisternal pressure and force the milk flow through the teat canal. The pressure exerted on the teat during hand milking depends on the patency of the teat canal (McDonald and Witzel, 1966). Although in the current experiment, the pressure exerted on the teat was not measured, we assumed that it was similar to that used in cattle or slightly higher (33.3 to 46.66 kPa; McDonald and Witzel, 1966). As this force depends on the hardness of the teat canal, the vacuum needed to open the teat canal in Murciano-Granadina goats is greater (35 kPa; J. R. Díaz, unpublished data) than that reported in bovines (17–20 kPa; Weiss et al., 2004). It is possible that because the teat is not subject to vacuum, the accumulation of liquids in the teat end may be less compared with that in MM or that the manual pressure applied to the teat tissues in HM may have been sufficient to assist in the re-evacuation of the accumulated liquids, which occurred in MM during the “D” phase of pulsation (milking phase).

The recovery time for TWT, TWA, TEWA, and TCL with all milk removal methods was greater than 10 h, which indicates that although MM caused greater increases in TWT and TWA immediately after milking, no differences were found in teat recovery time between machine milking and the methods of reference. Moreover, all variables were greater after milking than before with all tested methods and, although the variables did not reach premilking values at 10 h, most

variables reached lower values at 10 h than immediately after milking in KS, CATH, and MM, indicating a gradual recovery. Moreover, the values were recovered before the following milking, as we observed no day effect on the premilking values, no differences were found between the treatments before milking, and the values obtained were similar to those reported by Díaz et al. (2013) in the same breed.

Although no differences in recovery time were found in the different trials, a different recovery pattern was observed with HM. In general, the maximum values of the different ultrasound variables were obtained after milking in CATH, KS, and MM. These results agree with other published data in goats: Fahr et al. (2001) obtained the greatest increases in TWT and TCL immediately after machine milking compared with 1 h after milking. Ślósarz et al. (2010) also found maximum values of TWT and TCL immediately after milking compared with 4 and 10 h after milking. On the other hand, Wójtowski et al. (2006) found the greatest values for TWT and TCL after 4 h of machine milking.

In all 3 experiments, the measured variables followed a similar pattern after MM. This indicates that the changes in teat tissues caused by properly performed MM are reversible and performance was similar to removal methods considered physiologic. The observed evolution of the teat after milking and the data obtained following removal by catheter (experiment 2) indicate that factors other than removal method, such as intramammary pressure, may influence changes in teat wall thickness.

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