J. Dairy Sci. 97:5012–5016
http://dx.doi.org/10.3168/jds.2014-7934

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

M. Alejandro, A. Roca, G. Romero, and J. R. Díaz[1]
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-

Received January 11, 2014.
Accepted April 4, 2014.
[1]Corresponding 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**, cm^2), teat end wall area (**TEWA**, cm^2), 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 ith treatment (reference method of each experiment or MM); β_j is the effect of the jth period (first or second); $\gamma_k(\delta_l)$ is the effect of the kth experiment day (first or second) nested in the lth period (first or second); $\alpha\beta_{ij}$ is the interaction between treatment and period; $\kappa_m(\varepsilon_n)$ is the random effect of the mth gland (left or right) nested in the nth 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 ith moment (−1, 0, 1, 2, 3, 4, 6, 8, 10 h); β_j is the effect of the jth period (first or second); $\gamma_k(\delta_l)$ is the effect of the kth experiment day (first or second) nested in the lth period (first or second); $\kappa_m(\varepsilon_n)$ is the random effect of the mth gland (left or right) nested in the nth 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