Influence of Pulsation Rate on Udder Health and Teat Thickness Changes in Dairy Ewes

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ABSTRACT

In this work on machine milking of ewes, pulsation rates of 120 and 180 cycles per min were compared, both with a pulsation ratio of 50:50 and a vacuum level of 36 kPa, comparing intramammary infection (IMI), somatic cell count (SCC) and teat end thickness changes. To this end, two groups of 20 Manchega ewes were used in a crossover experimental design with two experimental periods of 24 d for each. Bacterial exposure of all teats was increased by dipping them in a suspension of *Staphylococcus simulans* at four consecutive milkings of each period. Pulsation rate of 180 cycles per min, compared with 120 cycles per min, had no negative effect upon new IMI (11 and 16% of ewes infected, respectively) and SCC. No teat end lesions were observed in those animals milked with the two pulsations assayed. Also, teat thickness changes (−0.38 and −0.36 mm at 120 and 180 cycles per min, respectively) were not affected significantly. Finally, in absence of IMI, the two pulsation rates assayed did not affect the SCC.

(Key words: intramammary infection, pulsation rate, somatic cell count, teat thickness)

INTRODUCTION

In machine milking, the main purpose of pulsation is to limit the development of congestion and edema in teat tissues while, in addition, helping to reduce the rate of new IMI (Mein, 1992). In cows, many studies have been carried out to determine how pulsation influences udder health status (Spencer, 1989; Bramley, 1992) and teat end condition (Hamann et al., 1994). Thus, several works have found an increase in the new

infection rate with pulsation failure such as the absence of pulsation (Reitsma et al., 1981) and an insufficient duration of liner closure (Reitsma et al., 1981) or of d phase pulsation (O'Shea et al., 1984; Osteras et al., 1995). To this end, current international milking standards for cows (ISO, 1996) specify a minimum d phase of 150 ms and 15% of the pulsation cycle. Nevertheless, the importance of liner collapse frequency in the incidence of IMI is not clear. Some works have found a worsening of udder health status with pulsation rates of 75 cycles/min (Walsh and Nyhan, 1969) or lower than 55 cycles/min (Osteras et al., 1995). On the contrary, other experiments with different pulsation rates and ratios indicate that the load applied during collapse is more critical than the collapse frequency (Bramley, 1992). On the other hand, although the SCC varies mainly in line with infection status, SCC in uninfected cows may also vary slightly according to physiological factors, such as number and state of lactation (Harmon, 1994; Schepers et al., 1997); however, SCC in uninfected cows is not influenced by pulsation rate (Olney and Scot, 1983) and other milking conditions (vacuum level and overmilking; Olney and Mitchell, 1983). The biological effect of pulsation on teat tissues could be estimated by measuring teat thickness changes (Hamann and Mein, 1988; Hamann et al., 1996); this measurement has been related with a higher risk of infection (Hamann, 1989) and a higher incidence of clinical mastitis (Ronningen and Reitan, 1990). Teat thickness after milking increases with pulsation ratio, but decreases progressively as pulsation rate rises to between 20 and 80 cycles/min (Hamann et al., 1994; Hamann and Mein, 1996).

Few experimental works have studied the influence of machine milking on udder health status and teat condition in dairy ewes. Moreover, the quantitative results obtained in bovine should not be extrapolated a priori to the ovine, given the differences that exist in the mechanical milking of both species. Thus, ewes are usually milked with higher pulsation rates (120 to 180 cycles/min) and lower milking vacuum (32 to 40 kPa)

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and pulsation ratio (50:50; Billon et al., 1999). These high pulsation rates are used mainly because pulsation rates lower than 120 cycles/min produce a worse ejection reflex and a lower milk extraction at milking in ewes (Le Du, 1985; Marnet et al., 1996). However, no studies are available that have compared the two pulsation rates more frequently used, 180 and 120 cycles/min, with respect to the presence of new IMI or teat-end condition. Furthermore, there is little and noncoincident information on how these pulsation rates influence SCC. In several works in which pulsation rates of 180 to 120 cycles/min (Molina et al., 1999) or 180 to 90 cycles/min (Labussière et al., 1978) have been compared, no significant effect on SCC was found. Nevertheless, in other experiments, both an increase (Paz-zona et al., 1993) and a decrease (Fernandez et al., 1999) in SCC have been reported at 180 cycles/min. On the other hand, although noninfectious SCC variation factors have also been described in ovine (Bergonier et al., 1994), it is still not known how the machine milking characteristics, and particularly pulsation rates of 120 and 180 cycles/min, affect SCC in the absence of IMI.

The aim of this work was to study the effect of the two pulsation rates more frequently used in ewes, 120 and 180 cycles/min, both with a pulsation ratio of 50:50, on the IMI, SCC and teat-end thickness changes. Given that on commercial ovine farms teat dipping with iodine (or another germicide) after milking is not a very common practice as an IMI control method, the comparison of the two pulsation rates has been posited in both situations, i.e., in teats dipped and not dipped with iodine.

MATERIALS AND METHODS

Experimental Design

This work was carried out on the experimental farm flock of the Animal Science Department of the Polytechnic University of Valence. The animals were stabled throughout the lactation period and were machine milked twice daily at 0800 and 1730 h. For 3 wk after lambing, ewes were milked with the pulsation rate of 120 cycles/min (preexperimental period). Next, 40 ewes without IMI were selected from the flock and blocked into 20 pairs (10 first lactation and 10 of older ewes) based on parity, milk production, and milking rate. Each pair was randomly divided, and one ewe was assigned the pulsation rate of 120 cycles/min, while the other was assigned the 180 cycles/min pulsation rate, for a period of 24 d (first experimental period). Then, all ewes were reversed between milking groups for another 24-d period (second experimental period). In the two milkings of the seventh and eighth day (four milkings) from initiation of each of the experimental periods, all

teats were immersed in a suspension of *Staphylococcus simulans* (5×10^7 cfu/ml) immediately before application of the milking unit. During all milkings in both experimental periods, only one teat per udder, always the same, was identified and dipped with iodine (0.5%) after milking. The teats to be dipped with iodine were chosen at random.

Equipment and Milking Method

Ewes were milked in a milking parlor (2×12) with six cluster and a milk pipeline at 1.0 m above the platform. Claw had a volume of 91 ml, with an air vent (6 L/min) and a manual vacuum shut-off valve. Liner was made of silicone and had the following features: mouthpiece bore: 19 mm; barrel bore: 17.5 mm; length 99 mm; rigidity (minimum vacuum necessary to close liner barrel within shell): 8 kPa. Three electromagnetic pulsators driven by an electronic control box supplied pulsation to the clusters (two clusters per pulsator). The milking machine and pulsation were monitored three times during the study, at the beginning of the preexperimental stage and each of the experimental periods. Vacuum level (36 kPa), pulsation ratio (50:50), and real reserve (130 L/min per milking unit) were unchanged throughout the experiment. Both pulsations were checked the same day at all teatcups of the parlor with an Alfatronic IV pulsation recorder (De Laval Agri, Tumba, Sweden); for each pulsation we therefore obtained 36 records (two teatcups per cluster, six clusters, 3 d; Table 1). Milking routine included machine stripping, by vigorous udder massage for 5 to 8 s just before the teatcups were removed. In addition, vacuum was always shut off at the claw before teatcup removal. In the preexperimental period, all teats were dipped in iodine (0.5%) after milking.

Bacterial Challenge

The strain of *S. simulans* utilized came from a gland with subclinical mastitis from a commercial flock. *Staphylococcus simulans* forms part of the group of coagulase-negative staphylococci, which are considered opportunist microorganisms that are normally found on healthy teat skin as well as on the hands of milkers, and may colonize the teat canal; however, we must point out that there are also works that have been unable to isolate *S. simulans* from teat skin of sheep (Burriel, 1998). The bacterial suspension (5×10^7 cfu/ml) used to dip the teats was prepared according to Hogan et al. (1990). Stock cultures of *S. simulans* were stored at -20°C in 50% glycerin. A 6-ml tube of trypticase soy broth was inoculated from a vial of stored stock culture and incubated at 37°C for 7 h. One milliliter of

Table 1. Pulsation cycle phases and pulsation rate (m $\pm$ DS) of two pulsations used in experiment.

	Pulsation ¹	
	120 cycles per min, 50:40	180 cycles per min, 50:50
Records (n)	36	36
Phase		
A, ms (%)	58 $\pm$ 2 (11.6 $\pm$ 0.4)	56 $\pm$ 4 (16.9 $\pm$ 1.3)
B, ms (%)	200 $\pm$ 3 (40.1 $\pm$ 0.7)	115 $\pm$ 6 (34.6 $\pm$ 1.8)
C, ms (%)	46 $\pm$ 2 (9.2 $\pm$ 0.3)	49 $\pm$ 2 (14.8 $\pm$ 0.6)
D, ms (%)	195 $\pm$ 1 (39.1 $\pm$ 0.2)	112 $\pm$ 2 (33.7 $\pm$ 0.5)
Pulsation rate, cycles/min	120.2 $\pm$ 0.1	180.6 $\pm$ 0.2

¹Pulsation rate, pulsation ratio.

this starter culture was used to inoculate 500 ml of trypticase soy broth, which was then incubated for 16 to 18 h at 37°C on a gyratory shaker. Cells were pelleted by centrifugation, washed twice with 0.1% proteose-peptone (number 3, Difco Laboratories, Detroit, MI) and resuspended in proteose-peptone. A standard plate count was conducted on the stock suspension before it was stored at 5°C. The plate count was used to determine the dilution required to prepare daily challenge suspensions containing 5×10^7 cfu/ml in TSB. Challenge suspension was prepared immediately before use.

DATA Acquisition

Bacteriological analysis, SCC and teat thickness of all teats were recorded at the morning milking once a week during the preexperimental period (three records) and every 6 d during the first and second experimental periods (four records in each).

To obtain bacteriological samples for analysis, teats were carefully cleaned with 70% ethanol and the first three streams of foremilk were discarded. Approximately 10 ml of milk were collected aseptically from each gland. Samples were kept at 4°C for a maximum of 12 h until bacteriological analysis. Twenty microliters of each sample were plated on blood agar plates (5% washed sheep erythrocytes; Biomerieux, Lyon, France). The plates were incubated aerobically at 37°C and examined at 24 h, 48 h, and 7 d. Cultures with five or more identical colonies were considered positive for IMI. Bacteria were identified according to the National Mastitis Council recommendations (Harmon et al., 1990). Identification of staphylococci was carried out using commercial micromethods (API STAPH; BioMérieux, Lyon, France).

SCC was determined with a Fossomatic 90 (A/S N Foss Electric, Hillerød, Denmark) in all samples taken for the bacteriological analysis (half udder samples) and in one sample of the whole milk obtained at the morning milking (udder sample). Samples remained under refrigeration for 24 to 48 h before being analyzed.

For teat condition records, the presence of visible lesions or alterations (red color, presence of callosity ring, subcutaneous hemorrhages) was observed in the teat skin and the zone around its canal. In addition, teat-end edema created by the milking machine was estimated with a "cutimeter" (no. 33865; Hauptner, D-42651 Solingen), measuring the teat thickness change immediately after milking, according to Hamann et al. (1996). "Teat thickness" has been defined as the distance (mm) between the spring-loaded caliper jaws for a given applied pressure. The difference in the measured teat thickness before and after milking largely reflects changes in the mass of tissue and fluid in the teat (Hamann and Mein, 1990). Consequently, measurements for each teat were taken before (m1) and after (m2) milking, and postmilking teat thickness changes were calculated as (m2 – m1) and, as a percentage, (m2 – m1)*100/m1. The cutimeter had a spring that exerted a force of 6.7 N., in line with a previous work (Díaz, 2000).

Statistical Analysis

Teat thickness changes data were analyzed statistically according to the following model:

$$Y_{ijkl} = \mu + T_i + I_j + P_k + e_{ijkl} \quad [1]$$

where

Y_{ijkl} = arithmetical mean of teat thickness changes at the first or second experimental period,

μ = mean,

T_i = fixed effect of the pulsation rate (120 or 180 cycles per min),

I_j = random effect of the teat,

P_k = fixed effect of the experimental period (first or second), and

e_{ijkl} = residual effect.

In the SCC data, there was a residual effect between the first and the second experimental period because the infected glands in the first period continued infected throughout the second period. Thus, SCC data were statistically analyzed separately for each experimental period. In the second experimental period, only ewes or half udders uninfected at the beginning of this period (35 ewes and 75 glands) were considered. In all cases, SCC data were $\log_{10}$ -transformed (Ali and Shook, 1980) before analysis because the SCC were not normally distributed. The statistical model used was:

$$Y_{ijkl} = \mu + T_i + I_j(T_i) + D_k + TD_{ik} + e_{ijkl}$$

where:

Y_{ijkl} = SCC in $\log_{10}$,

μ = mean,

T_i = fixed effect of the pulsation rate (120 or 180 cycles per min),

$I_j(T_i)$ = random effect of the ewe (data of whole milk udder) or half udder (data of the bacteriological analysis samples) nested within pulsation rate group,

D_k = fixed effect of the control day,

TD_{ik} = pulsation rate $\times$ control day interaction, and

e_{ijkl} = residual effect.

To determine the effect of the pulsation rate on SCC of uninfected glands or udders, we statistically analyzed $\log_{10}$ SCC data from ewes or half udders that remained uninfected during overall experiment (30 ewes and 70 half udders) using model [1] described previously. These statistical analyses were carried out with the Mixed procedure from the SAS program (SAS, 1996).

Association of pulsation rate and iodine with the frequency of new IMI were assessed by means of chi-square, utilizing the Freq procedure (SAS, 1996).

RESULTS

The number and proportion of new IMI in each of the two experimental periods are shown in Table 2. Pulsation rate had no significant effect on the proportion of new IMI either at half udder level (8 and 5% of IMI at pulsation rate of 120 and 180 cycles/min, respectively; $P = 0.50$) or at udder level (16 and 11% of IMI at 120 and 180 cycles/min; respectively $P = 0.47$); moreover, the pulsation rate effect on new IMI was not significant ($P > 0.05$) when the glands dipped with iodine and those not dipped with iodine were considered separately.

Most of the infections, eight out of 10, were caused by the same bacteria utilized to carry out the immersions (*S. simulans*), whereas the other two infections were caused by *Staphylococcus* spp. (coagulase-negative) and *Micrococcus* spp.; in these last two cases it was not possible to identify the species. Practically all new IMI were detected in the first 10 d after carrying out the bacterial immersion (two initial bacteriological analyses performed after the bacterial challenge).

All the infections caused by *S. simulans* were persistent, remaining until the end of lactation; they also provoked an important inflammatory response, as the SCC were generally over 1,000,000 cells/ml. In contrast, the SCC of the healthy glands were usually lower than 150,000 cells/ml.

In the analysis performed at glandular and udder level, pulsation rate had no significant effect upon SCC in the first or second experimental period (Table 3). Moreover, when considering only the glands or udders that were not infected in either of the two experimental periods (70 glands and 30 ewes), it was also found that the two pulsation rate levels did not present any significant differences in SCC (Table 3). This may also be seen in Figure 1, where the evolution of the arithmetical means of the SCC of the glands remaining healthy in both experimental periods is presented.

Finally, it was not possible to ascertain that pulsation rate affects teat end condition. On the one hand, no teat end lesions or alterations were observed in those animals milked in the two pulsations assayed. On the other, the teat thickness change after milking in both pulsations did not differ significantly (-0.38 and -0.36 mm; $P > 0.1$; Table 4). In Figure 2, it may be observed that in the first experimental period, the batch of sheep milked at 120 cycles/min presented a slightly lower teat thickness change, whereas during the second experimental period the thickness change differences between the two batches did not vary, despite having interchanged the pulsation rate, which shows that the minor thickness change differences were due to the batch of animals and not to pulsation rate.

DISCUSSION

In this experiment, it was determined that, when milking with a 36-kPa vacuum level, the pulsation of 180 cycles/min and 50:50 did not increase new IMI or SCC compared with the pulsation of 120 cycles/min and 50:50. This result concurs with those of other works (Peris, 1994; Molina et al., 1999), where, when milking at different vacuum levels (34 to 44 kPa), it was not found that these two pulsations affected the udder health, estimated from the SCC or the CMT. On the other hand, this study did not allow confirmation of

Table 2. New IMI at each experimental period according to the pulsation rate used and application or not of iodine after milking.

Experimental period ¹	Pulsation rate (cycles per min)	New half udders infected ³			New ewes ³ infected
		Iodine ²	No Iodine	Total	
First	120	0/20	2/20	2/40	2/20
	180	0/20	3/20	3/40	3/20
Second	120	3/20	1/17	4/37	4/17
	180	0/20	1/18	1/38	1/18
Global	120	3/40 (7%)	3/37 (8%)	6/77 (8%)	6/37 (16%)
	180	0/40 (0%)	4/38 (11%)	4/78 (5%)	4/38 (11%)
<i>P</i>		0.08 ^{NS}	0.72 ^{NS}	0.50 ^{NS}	0.47 ^{NS}

¹In each experimental period all teats were challenged in four consecutive milkings in a suspension of *Staphylococcus simulans* (5×10^7 cfu/ml).

²Only one teat per udder was dipped with iodine after milking in all milkings of the two experimental periods.

³No. new IMI/no. total healthy udder halves or ewes at the outset of each experimental period.

previous results found by our research team (Fernández et al., 1999), where a lower SCC in the pulsation rate of 180 cycles/min was reported compared with 120 cycles/min (both with vacuum level of 36 kPa and pulsation ratio of 50:50).

Current quantitative recommendations for milking machines installations for small ruminants (Billon et al., 2002) show no specifications for pulsation characteristics, given the absence of any research relating these features with infection risk. In contrast, in the international standards for the machine milking of cows (ISO, 1996), detailed specifications for pulsation are set out, as d phase must have a minimum duration of 150 ms and represent 15% of the cycle. Moreover, in cows, some authors (Reistma et al., 1981) also recommend that duration of liner closure should be over 330 ms (one-

third of a second) per pulsation cycle in order to reduce the risk of new IMI. Pulsation at 120 cycles/min and 50:50 fulfils these minimum values, as the d phase has a duration of 195 ms, representing almost 40% of the cycle (Table 1) and, from the work by Le Du (1977), it may be estimated that the liner is in the closed position for 330 ms (65% of cycle). On the other hand, in pulsation at 180 cycles/min and 50:50, the d phase lasts for 112 ms (Table 1) and the liner is in closed position for 240 ms (72% of cycle; Le Du, 1977), which could be insufficient bearing in mind the previous recommendations for cows. However, this latter pulsation rate also fulfills two characteristics that may help to explain why no negative effect on udder health was reported. First, if the d phase is expressed as cycle percentage, the values encountered (33%) represent twice the minimum

Table 3. Effects of the pulsation rate used on SCC at half udder and udder level considering udder halves/ewes infected and not infected in each experimental period or udder halves/ewes that remained not infected throughout the experiment.

	Experimental period	Pulsation rate	Half udders			Udders		
			No. half udders	SCC		No. udders	SCC	
				Log SCC ¹	GM ²		Log SCC ¹	GM ²
Half udders/ewes infected and non-infected	First	120 p/min	40	4.73 ± 0.05	54	20	4.96 ± 0.05	91
		180 p/min	40	4.69 ± 0.05	49	20	4.89 ± 0.05	78
		<i>P</i>		NS			NS	
	Second ³	120 p/min	37	4.99 ± 0.07	98	17	5.08 ± 0.08	120
		180 p/min	38	4.88 ± 0.07	77	18	5.00 ± 0.08	100
		<i>P</i>		NS			NS	
Half udders/ewes not infected throughout the experiment ⁴	Global	120 p/min	70	4.74 ± 0.03	55	30	4.87 ± 0.03	75
		180 p/min	70	4.73 ± 0.03	54	30	4.93 ± 0.03	68
		<i>P</i>		NS			NS	

¹M ± SE.

²GM = geometrical mean.

³Only half udders/ewes not infected at the beginning of this experimental period were considered.

⁴Group A: 37 half udders and 17 ewes; Group B: 33 half udders and 13 ewes.

Table 4. Effect of pulsation rate on postmilking teat thickness changes ($m \pm SE$), as difference and as percentage relative to premilking values in ewes.

Experimental period	Pulsation	No. ¹	Teat thickness (mm)		Teat thickness change	
			Before milking	After milking	After-before ² , mm	% ³
First	120 p/min	40	5.42 $\pm$ 0.05	5.02 $\pm$ 0.04	-0.39 $\pm$ 0.04	-6.5 $\pm$ 0.8
	180 p/min	40	5.25 $\pm$ 0.05	5.06 $\pm$ 0.04	-0.19 $\pm$ 0.04	-2.6 $\pm$ 0.9
Second	120 p/min	40	5.58 $\pm$ 0.4	5.23 $\pm$ 0.03	-0.35 $\pm$ 0.04	-5.2 $\pm$ 0.8
	180 p/min	40	5.68 $\pm$ 0.4	5.15 $\pm$ 0.03	-0.52 $\pm$ 0.04	-8.3 $\pm$ 0.8
Global	120 p/min	80	5.50 $\pm$ 0.07	5.12 $\pm$ 0.06	-0.38 $\pm$ 0.03	-5.9 $\pm$ 0.6
	180 p/min	80	5.47 $\pm$ 0.07	5.11 $\pm$ 0.06	-0.36 $\pm$ 0.03	-5.5 $\pm$ 0.6
	P		NS	NS	NS	NS

¹Number of teats.²After milking – before milking.³(after milking – before milking)*100/before milking.

value (15%) recommended in bovine. Second, the change in teat thickness in the two assayed pulsation rates was similar, which would indicate that both pulsations, despite their differences, provoked the same biological effects in teat tissue. Thus, the observation that pulsation at 180 cycles/min and 50:50 has no negative effects on udder health enables us to deduce that the current recommendations on machine milking for bovine should not be extrapolated to the ovine *a priori*, given the differences existing in mechanical milking of both species.

Another point to emphasize is that 30% of infections occurred in glands in which iodine had been applied to the teats. Two hypotheses could be formulated to ex-

plain this fact. One possible explanation is that after teat dipping, a determined number of bacteria lodged in the teat end or its canal might manage to survive the iodine action, in such a way that they could colonize the teat canal, and, by growing, reach the udder interior. Another alternative hypothesis is that during machine milking of ewes, the transfer of germs to the interior of the canal or the teat sinus may occur and, in this way, these germs could escape the postmilking iodine application. In cows, this transfer of bacteria has been associated with impact phenomena (Thiel and Mein, 1979) and possibly also with reverse pressure gradients across the teat canal (Rasmussen et al., 1994). Moreover, it is likely that at field level these transference mechanisms are even more common, given that

Figure 1. Evolution of the SCC arithmetical mean in two groups of udder halves of ewes that remained uninfected throughout the experiment (group A, $n = 37$, —; group B, $n = 33$, ----) and were milked alternately with a pulsation rate of 120 (■) or 180 (○) cycles per min. Pulsation ratio (50:50) and vacuum level (36 kPa) were unchanged throughout the experiment. Records were every 7 d at the preexperimental period and every 6 d thereafter.

Figure 2. Evolution of the postmilking teat thickness change in two groups of 20 ewes (group A, $n = 40$ teats, —; group B, $n = 40$, ----) milked alternately with a pulsation rate of 120 (■) or 180 (○) cycles per min. Pulsation ratio (50:50) and vacuum level (36 kPa) were unchanged during throughout the experiment. Records were every 7 d at the preexperimental period and every 6 d thereafter.

in this experiment certain situations that generate high vacuum fluctuations in teat end were avoided. Thus, great care was taken to avoid air entering the teatcups during machine stripping and, moreover, the milking vacuum was always shut off from the claw before teatcups were removed.

In this work, it was found that the two pulsation rates assayed did not affect the SCC of the glands or udders in the absence of IMI. In addition, our research group recently reported that other milking conditions such as vacuum level (36 vs. 42 kPa) and overmilking (1.5 to 2 min) did not cause any stress or irritation that would lead to an increase in SCC in the absence of mastitis infections (Díaz, 2000) either. The works carried out previously in cows have also shown that pulsation rate (30 to 120 cycles/min; Olney and Scott, 1983), overmilking as well as vacuum level (Olney and Mitchell, 1983) did not affect SCC in those animals without IMI. Therefore, it may be concluded that ewes and cows coincide in that the customary machine milking conditions will increase the SCC if they influence the incidence or severity of the IMI, but will not affect the SCC of those animals free from IMI.

Finally, it must be pointed out that the teat thickness change in both pulsations assayed was negative, so that in both cases thickness was reduced after milking by about 0.3 mm (5%). Other authors, milking at 180 cycles/min and 50:50 with a vacuum level of 32 to 36 kPa, also found negative values of teat thickness change, ranging between -0.1 mm (Marnet et al., 1996) and -0.5 to -0.6 mm (Mckusick et al., 2000). In ewes, Marnet et al. (1996) cited a decrease in teat thickness change when pulsation rate was increased from 60 cycles/min (+0.02 mm) to 180 cycles per min (-0.09 mm), with milking vacuum (36 kPa) and pulsation ratio (50:50) remaining constant. In bovine, it is also reported that, in general, increasing pulsation rate from 20 to 80 cycles/min does not affect the teat thickness measurements before milking, but tends to diminish them after milking and, consequently, teat thickness change (Hamann et al., 1994; Hamann and Mein, 1996). In contrast, in our study no decrease in teat thickness measurements after milking was found when pulsation rate was increased from 120 to 180 cycles/min. In bovine, changes in teat thickness have been linked with a higher risk of infection (Hamann, 1989) and it has been proposed that machine-induced changes in teat thickness would have to be less than $\pm 5\%$ (Hamann and Mein, 1996). Nevertheless, in ewes no research results have as yet related these measures with the risk of new IMI.

CONCLUSIONS

This experiment has shown that in machine milking of ewes, the raising of pulsation rate from 120 to 180

cycles/min, both with a pulsation ratio of 50:50 and milking vacuum of 36 kPa, had no negative effect upon udder health or teat end edema. Furthermore, in the absence of IMI, the two pulsation rates assayed did not affect the SCC of the milk.

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