Journal of Dairy Research (2012) **79** 375–382. doi:10.1017/S0022029912000362

Effect of mid-line or low-line milking systems on milking characteristics in goats

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Received 01 February 2012; accepted for publication 25 April 2012

Two experiments were carried out to compare mechanical milking in mid-level (ML) and low-level (LL) milkline in goats. The first trial used 40 intramammary infection (IMI)-free goats that had been milked in ML during a pre-experimental period of 4 ± 1 weeks post partum. These animals were divided into two groups ($n = 20$), randomly assigning each group to ML or LL milking for a 17-week experimental period. During this period, several strategies were applied to increase teat exposure to pathogens in both experimental groups. The IMI rate was the same in both experimental groups (30% of goats), although the majority of new infections appeared earlier in ML (weeks 1–5) than in LL (weeks 7–16). Teat-end vacuum range (maximum minus minimum vacuum) was higher in ML than in LL, but no significant differences were found in the remaining variables [milk production and composition, somatic cell count (SCC), frequency of liner slips + teatcups fall off]. In the second experiment, in a crossover design (54 goats in fourth month of lactation; 2 treatments, ML and LL, in 2 experimental periods each lasting 1 week) it was observed that both the milk fractioning (reduced machine milk and increased machine stripping) and average machine milk flow worsened slightly in ML milking; in contrast, no differences were observed in total milking time or teat thickness changes after milking. It was concluded that the differences found between ML and LL are not sufficiently important to discourage breeders from using ML in goat milking.

Keywords: Milking machine, milkline, mid-line, low-line, goat, mastitis.

In recent years, sheep and goat farmers have shown increasing interest in installing milking machines with a mid-line (ML) milking system, rather than low-line (LL). This is because in a milking parlour with two platforms, an ML milkline is usually located in the centre of the pit, so that one milking cluster can be used on both platforms and it is therefore possible to install half as many milking units as in an LL milkline. Consequently, with an equal number of milking stalls, the installation of an ML usually cuts initial investment by around 25–35% (Díaz et al. 2004), while the lower cost also facilitates the installation of certain automatic devices associated with milking units, such as automatic cluster removers and electronic milk meters.

However, when the milkline is above the animal standing level (mid-level if height is between 0 and 1·25 m; high-level if height greater than 1·25 m; ISO 3918: 2007) the milk goes up the long milk tube, forming torrents that take up the entire pipe section, causing a decrease in average teat end vacuum (Le Du, 1983) and an increase in vacuum fluctuations (Osteras & Lund, 1980; Díaz et al. 2004). These effects become more pronounced as the milk flow increases (Le Du, 1977; Ambord & Bruckmaier, 2010), the higher the milkline height (O'Shea, 1987) and the lower the air intake in the claw (Murgia & Pazzona, 1999). In principle, these issues could affect milking efficiency and, in particular, mastitis rates, although no work comparing ML with LL milking goats has been published.

In ewes it has not been demonstrated that ML milking adversely affects udder health (Le Du, 1983; Díaz et al. 2004). In contrast, in dairy cows the high line has occasionally been associated with a higher somatic cell count (SCC) in bulk milk (Czediwoda, 1991; Garces et al. 2006) or a greater likelihood of impact presence during low milk flow (Thompson & Pearson, 1979). Moreover, in ewes

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Le Du (1983) and Díaz et al. (2004) found no effect of milking pipeline height (LL *v*. ML) on milk production and composition or teatcup fall-off.

Since no published work comparing ML and LL milking in goats were available, the present study was proposed in order to assess the effects on intramammary infection (IMI) rate, milk production and composition, teat tissue condition and, finally, milk emission kinetics.

Material and Methods

Experimental design

Two experiments were carried out on the Murciano–Granadina breed goat herd of the Universitat Politècnica de València. The first evaluated mastitis incidence, milk yield and composition, SCC, liner slip/teatcup fall-off and macroscopic changes of teats (visible lesions or alterations). Teat thickness changes and milk emission kinetics were assessed in the second experiment.

First experiment. Forty goats (15 primiparous and 25 multiparous) that had been milked in ML for a pre-experimental period of 4 ± 1 weeks post partum were used. These animals were split into two groups ($n = 20$) according to lactation number, production level and milk flow, and each group was assigned at random to ML or LL for a 17-week experimental period. The milking order in both groups was alternated each week. Throughout the experimental period, two strategies were used to increase teat exposure to pathogens during milking: (a) teats were not post-dipped with iodine; (b) each day, infected goats were milked in ML and LL, before milking each experimental group.

In the pre-experimental period, the following variables were monitored in each animal weekly: milk yield and composition, liner slip/teatcup fall-off, SCC, visual teat condition and bacteriological analysis (per gland). Moreover, in the last week of this period the milk flow was also monitored for each animal on two consecutive days.

In the experimental period, bacteriological analysis of the glands continued to be recorded weekly, while the other variables were monitored each 10–14 d (10 records). Likewise, towards the middle of this period, vacuum measurements around the teat in one day's milking were recorded.

Second experiment. Fifty-four Murciano–Granadina goats in the fourth month of lactation were used. The experiment lasted 3 weeks: a 1-week pre-experimental period and a 2-week experimental period, in a crossover design (2 × 2). In the pre-experimental period, the goats were all milked in ML and machine milk production and milk flow rate were recorded on two consecutive days. In line with these two variables, the animals were divided into two groups, randomly assigning one of the two treatments (ML or LL milking) for 7 d. In the last two days of this period, the teat thickness changes after milking and milk emission kinetics were recorded in each animal. Treatments (ML and LL) for the two groups of 27 goats were then exchanged for another 7-d period, recording the same variables on the last two days.

Milking routine and material

Animals were always milked once a day (8·30) following a routine that included machine stripping and manual cluster removal. Post-dipping with iodine (0·15%, Proactive Plus, DeLaval, Drongen, Belgium) took place in the pre-experimental period (4 ± 1 week) of the first experiment and throughout the second experiment.

The milking parlour (2 × 12) had two milk pipelines installed, with 6 clusters in ML and 12 clusters in LL. The ML milkline, dead end type, was 52 mm in diameter and 520 cm in length and was located at 112 cm above goat standing level. The LL milkline, looped type, was 52 mm in diameter and 1500 cm in length and was located at 40 cm below goat standing level. Both milklines were stainless steel, with 0·2% slope toward the receiver and a 61-cm distance between milk inlet connections. Clusters were from Delaval Agri (Tumba, Sweden). In LL Almatic™ cluster G50 was used. The same cluster was used in ML, but with a claw (from the DeLaval cluster SG-TF80; claw volume 100 ml). The short milk tube diameters were 10·5 and 9·4 mm in LL and ML, respectively. A different nominal vacuum was set (40 kPa in ML and 37 kPa in LL) so that the average teat-end vacuum, in the absence of milk flow during milking, was similar in both types of milking systems. The effective reserve (ML: 750 l/min; LL: 950 l/min) complied with international recommendations (higher than 512 and 804 l/min in ML and LL, respectively; extra air for automatic teatcup valves: 32 l/min; ISO 5707, 2007). The pulsation rate (90 cycles/min) and ratio (60%) were the same in ML and LL.

Variables measured

In the first experiment, milk yield and milk fraction yields [machine milk (MM) and machine stripping milk (MSM)] were monitored with milk jars (Esneder, Ind. Berango, Spain), while in the second experiment, the emission kinetics were recorded with electronic milk meters (MM25SG, De Laval Agri, Tumba, Sweden). In the latter case, the following variables were calculated: (a) MM and MSM volume (ml); (b) average milk flow (ml/min) during first minute of milking and in MM and MSM fractions; (c) maximum milk flow (ml/min), with readings every 2 s, in MM and MSM fractions; (d) time (s): time to reach the maximum flow rate in MM fraction, MM time, MSM time and total milking time (MM time + MSM time).

Milk composition (fat, protein, lactose and dry matter; g/kg) and SCC (cells/ml) were analysed in 40 ml milk (MM + MSM) from each animal, taken straight from the milk jars. Both analyses were performed using automated

https://doi.org/10.1017/S0022029912000362 Published online by Cambridge University Press

equipment (composition: MilkoScan FT120; SCC: Fosssomatic 5000; Foss Electric, Hillerød, Denmark). To obtain samples for bacteriological analysis, teats were carefully cleaned with 70% ethanol and the first three streams of foremilk were discarded. Approximately 5 ml of milk was collected aseptically from each gland. Samples were kept at 4 °C for a maximum of 12 h until bacteriological analysis. Twenty-microlitres of each sample were plated on blood agar plates (5% washed sheep erythrocytes; Biomerieux, Lyon, France). 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. Bacterial groups were identified according to National Mastitis Council recommendations (Harmon et al. 1990).

At each record in the first experiment, the number of animals that had suffered liner slip (abrupt air intake via liner, without it becoming detached from the udder) or teatcup fall-off was recorded.

Teat-end vacuum were recorded with Pulsatortester PT-V equipment (Exendis, Almere, Netherlands): one of the sensors was connected to the short milk tube, near the liner while the other sensor was connected to the short pulse tube (response rate of recording system: 1015 kPa/s). Vacuum measurements in the short milk tube were done with a sample rate of 800 Hz during 4 s (6 pulsation cycles), and the equipment calculated the average, maximum and minimum vacuum. Both in ML and LL, these readings were taken in 6 milking clusters in 3 different situations: (a) with teatcups plugged prior to milking; (b) when milking 6 animals (one per cluster), at peak flow time (from 30 to 60 s after milk flow onset); (c) in milking the same 6 animals as before, but when milk flow ceased.

For teat condition records, the presence of visible lesions or alterations (red colour, presence of callosity ring, subcutaneous haemorrhages) was observed in the teat skin and the zone around its canal. In addition, in the second experiment, teat-end oedema created by the milking machine was estimated in both teats per animal (108 teats) with a 'cutimeter' (no. 33865; Hauptner, D-42651 Solingen) according to Hamann et al. (1996) and Peris et al. (2003). To this end, the teat wall thickness was measured before (A) and after (B) milking and postmilking teat thickness changes were calculated as difference (B − A) and as percentage ((B − A) *100/A).

Statistical analysis

First experiment. In the experimental period, milk production and composition variables were analysed using the following repeated measures statistical model:

$$Y_{ijk} = \mu + L_i + G_j(L_i) + D_k + L_i \times D_k + COV + e_{ijk} \quad (1)$$

where: Y_{ijk}, analysed variable; L_i, fixed line effect ($i=1$ Mid Line; $i=2$ Low Line); Gj (L_i), random goat effect j ($j=1$ to 40) nested within Line i; D_k, fixed effect of record Day k ($k=1$ to 10); L_iD_k, fixed effect of Line × Day interaction; COV, covariable effect (for each goat, average for the last two pre-experimental records); e_{ijk}, residual error.

SCC data were $\log_{10}$-transformed (Ali & Shook, 1980) and were analysed with model (1), but without considering the covariate.

These statistical analyses were performed according to Littell et al. (1998) using PROC MIXED (SAS, 2002).

Teat-end vacuum variables were analysed using the following model:

$$Y_{ijk} = \mu + L_i + MU_j(L_i) + MC_k + L_i \times MC_k + e_{ijk} \quad (2)$$

where: Y_{ijk}, recorded variable: average, maximum, minimum and range (max − min) vacuum; L_i, fixed line effect ($i=1$ Mid Line; $i=2$ Low Line); MU_j (L_i), fixed effect of milking unit j ($j=1$ to 6) nested to L_i; MC_k, fixed effect of milking condition ($k=1$ teatcups plugged; $k=2$ milking with high flow; $k=3$ milking with zero flow); L_iMC_k, fixed effect of line milking condition interaction; e_{ijk}, residual error.

Teatcup fall-off and intramammary infection rates were statistically analysed by X^2 test using PROC FREQ (SAS, 2002).

Second experiment. Teat thickness changes and milk emission kinetics variables were statistically analysed using the following model:

$$Y_{ijkl} = \mu + L_i + T_j + P_k + D_l(P_k) + e_{ijkl} \quad (3)$$

where Y_{ijk}, analysed variable; L_i, fixed line effect ($i=1$ Mid Line; $i=2$ Low Line); T_j, fixed effect of teat (teat thickness change variables; $j=1$ to 108) or animal (emission kinetics variables; $j=1$ to 54); P_k = fixed effect of experimental period k ($k=1$ and 2); $D_l(P_k)$ = fixed effect of day l($l=1$ and 2) in experimental period k; e_{ijkl} = residual error.

Statistical analyses (2) and (3) were performed with PROC GLM (SAS, 2002).

Results

Teat-end vacuum

The four vacuums recorded (average: VMEAN; maximum: VMAX; minimum: VMIN and vacuum range, i.e. maximum − minimum: VRANGE) were significantly affected by the line (ML *v*. LL; $P<0{\cdot}001$), milking conditions ($P<0{\cdot}001$) and interaction between both factors ($P<0{\cdot}001$). Table 1 shows the mean values of these variables.

In non-milking conditions, with teatcups plugged, VMEAN was higher in ML than in LL (40·1 *v*. 37·0 kPa, $P<0{\cdot}001$), which was to be expected, since nominal vacuum was higher in ML. However, in milking conditions with flow, VMEAN dropped considerably in ML, whereas little variation was observed in LL (33·6 and 36·5 kPa in ML and LL respectively; $P<0{\cdot}001$). In milking without flow, VMEAN was similar in ML (37·1 kPa) and LL (36·6 kPa), although the differences became significant ($P<0{\cdot}05$).

https://doi.org/10.1017/S0022029912000362 Published online by Cambridge University Press

Table 1. Teat-end vacuum (kPa) variables in mid-line (LM) and low-line (LL) milking systems under different milking conditions†

Variable	Milkline	Milking condition: Teatcups plugged	Milking with milk flow	Milking without milk flow	SEM
Mean vacuum (VMEAN)	ML	40·1[a]	33·6[b]	37·1[c]	0·1
	LL	37·0[a]	36·5[b]	36·6[ab]	0·1
	P	***	***	*	–
Max. vacuum (VMAX)	ML	41·2[a]	39·2[b]	39·6[c]	0·1
	LL	37·7[a]	37·4[a]	37·3[a]	0·1
	P	***	***	***	–
Min. vacuum (VMIN)	ML	38·6[a]	26·8[b]	33·2[c]	0·4
	LL	36·0[a]	33·9[b]	35·7[a]	0·4
	P	**	***	***	–
Vacuum Range (VRANGE = VMAX − VMIN)	ML	2·6[a]	12·4[b]	6·5[c]	0·5
	LL	1·7[a]	3·5[b]	1·6[a]	0·5
	P	NS	***	***	–

†For each milking condition, average of 6 records in 6 different clusters, with 5 pulsation curves by record
*$P<0·05$; **$P<0·01$; ***$P<0·001$; NS = Not significant ($P>0·05$)
[a,b,c]Means within a row without a common superscript letter differ ($P<0·05$)

Maximum vacuum (VMAX) was always higher in ML than in LL; in contrast, minimum vacuum (VMIN) was higher in ML only in non milking conditions (teatcups plugged), but in milking conditions (with and without flow) VMIN was lower in ML than in LL.

Vacuum ranges (VRANGE) in non-milking conditions were low and similar in ML (2·6 kPa) and LL (1·7 kPa), with no significant differences found. During flow milking, VRANGE increased significantly in ML (12·4 kPa) yet hardly varied in LL (3·5 kPa), so the differences between treatments were significant ($P<0·001$). We also note that during milking without flow, VRANGE was still significantly higher in ML than in LL (6·5 and 1·6 kPa; $P<0·001$). These greater vacuum fluctuations in ML, when in milking conditions (with and without flow), can also be seen in Fig. 1, representing teat-end vacuum during 5 pulsation curves in ML and LL, and in the 3 milking conditions considered.

Mastitis incidence

The incidence of IMI coincided in the group of animals milked in ML and the LL, as 6 goats in each batch suffered mastitis. Thus, the IMI rate was 30% in both experimental batches (6 goats with IMI from a total of 20 in each batch). All infections were unilateral and caused by coagulase-negative staphylococci (5 infections in ML and 4 in LL), *Streptococcus* spp. (1 infection in ML) and Gram-negative bacilli (2 infections in LL). Both in ML and LL, two of the infections became clinical mastitis. Notably, the majority of new infections appeared sooner in ML (5 infections between weeks 1 and 5 of the experimental period; 1 infection in week 9) than in LL (6 infections between weeks 7 and 16). In fact, if we consider only the first 5 weeks of the experiment, the new IMI was significantly ($P<0·05$) higher in ML (5 infected out of 20) than in LL (0 infected out of 20).

Production, composition, SCC and teatcup fall-off

Milk production (MM, MSM and total milk), milk composition (fat, protein, lactose and dry matter) and SCC variables did not differ significantly between the two experimental lots (Table 2). Record Day factor significantly affected all the cited variables except for MSM, but the Line × Day interaction had no significant effect on any of these variables.

Throughout the experiment, teatcup fall-off was quite rare, representing only 10% of liner slips. For this reason, both variables were analysed jointly. In the pre-experimental period, the frequency of liner slip + teatcup fall-off were similar in both batches (35 and 36%), whereas in the experimental period the LL milked group presented a slightly higher liner slip + teatcup fall-off rate compared with the batch milked in ML (22% *v*. 17%), although this difference did not reach significance levels.

Teat condition and milk emission kinetics

In the first experiment, no teat-end lesions or alterations were observed in any goats milked in ML or LL. Besides, the teat thickness change after milking in both experimental groups did not differ significantly when it was expressed as difference (0·17 *v*. 0·19 mm) or as percentage (3·92 *v*. 4·31%; Table 3).

Milk emission kinetics results are presented in Table 4. Average milk flow in the first minute of milking and in the machine milk fraction were slightly lower in ML than in LL (first minute flow: 610 *v*. 641 ml/min; $P=0·08$; average flow: 551 *v*. 580 ml/min, $P<0·05$) but the maximum flow and the milking time in the machine milk fraction (947 *v*. 937 ml/min and 118 *v*. 122 s, respectively) did not differ significantly between the two treatments. In contrast, in the machine stripping milk fraction the average flow was higher in ML

https://doi.org/10.1017/S0022029912000362 Published online by Cambridge University Press

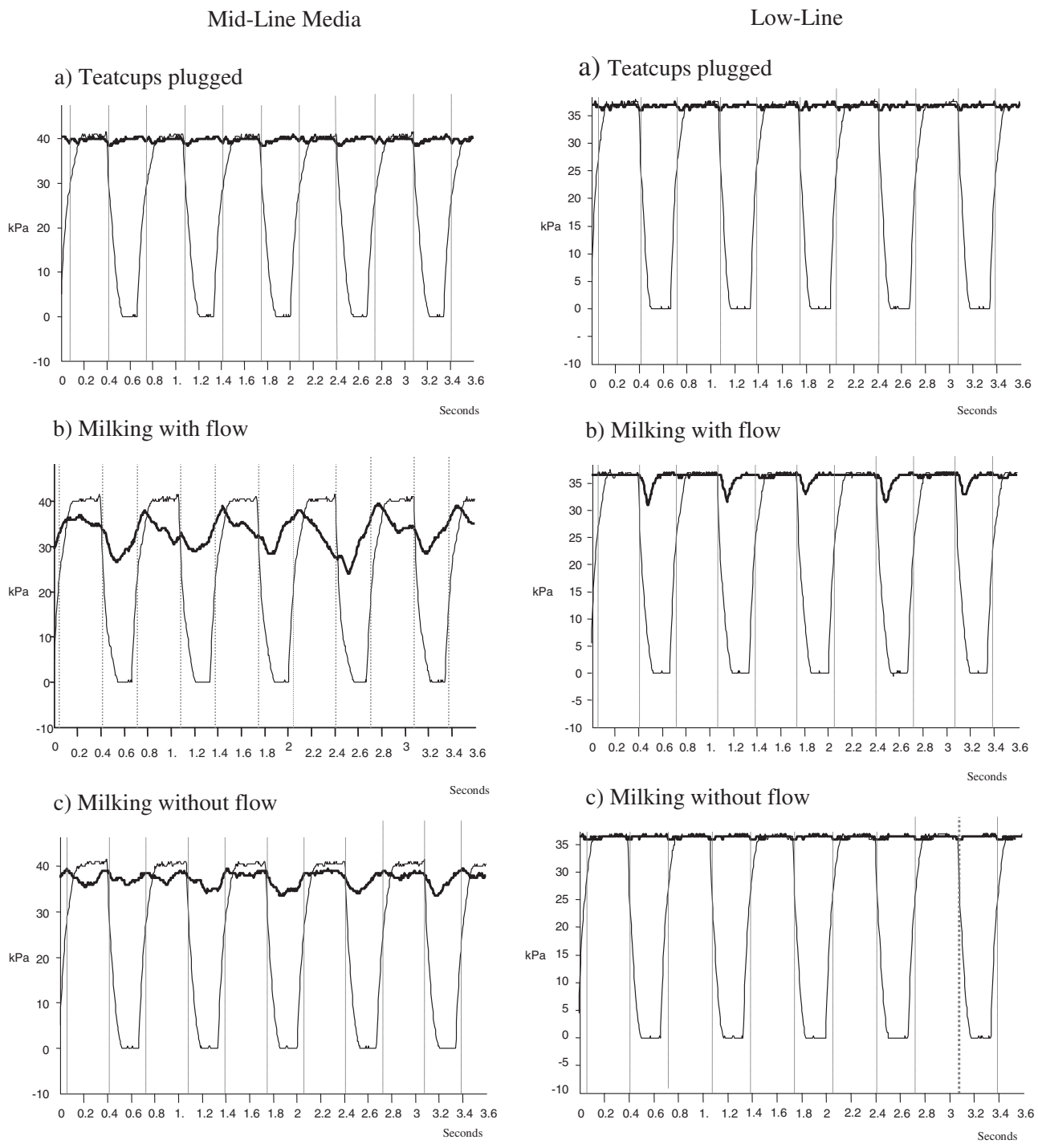

Fig. 1. Examples of teat-end vacuum (wide line) recorded in the three milking conditions studied (a, b, c) in a mid-line and low-line milking system. The narrow line is the pulsation chamber vacuum.

than in LL (259 *v*. 181 ml/min; $P<0{\cdot}001$) and the same held for maximum flow (405 *v*. 259 ml/min; $P<0{,}001$) and milking time (22 *v*. 16 s; $P<0{\cdot}001$) of this milk fraction. Overall, the total milking time (machine milk and machine stripping milk fractions) was similar in ML and LL (140 *v*. 138 s; $P>0{\cdot}1$).

Another notable aspect of Table 4 is that, in the second experiment, ML tended to slightly, but significantly, lower the machine milk fraction volume (989 *v*. 1062 ml; $P<0{\cdot}001$) and increase machine stripping milk fraction volume (97 *v*. 61 ml; $P<0{\cdot}001$). However, total milk did not differ significantly between ML and LL (1088 *v*. 1125 ml).

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Table 2. Means (±SE) of milk production and composition and somatic cell count (SCC), and frequency of liner slip + teatcup fall-off (LS + FALL), in two groups of 20 goats milked in a mid-line (ML) and low-line(LL) milking system during a 17-week experimental period (10 records)

Variable	Milkline		
	ML	LL	*P*
Milk production, ml/d			
Machine milk	1210 ± 57	1320 ± 57	NS
Machine stripping milk	102 ± 16	95 ± 16	NS
Total milk	1303 ± 61	1416 ± 61	NS
Milk composition, g/kg			
Fat	49·6 ± 1·1	49·8 ± 1·1	NS
Protein	35·3 ± 0·4	35·2 ± 0·4	NS
Lactose	47·6 ± 0·3	47·5 ± 0·3	NS
Dry matter	142·3 ± 1·5	142·1 ± 1·5	NS
SCC, cells/ml			
Log_{10} SCC	5·69 ± 0·08	5·61 ± 0·08	NS
Geometric mean (10^{-3})	490	408	–
LS + FALL,%	17	22	NS

NS = Not significant ($P > 0·05$)

Table 3. Means (±SE) of teat thickness measured with cutimeter before (BEFORE) and after (AFTER) milking and teat thickness changes, as a difference (DIFFERENCE) and as percentage of premilking values (PERCENTAGE), in 54 goats (108 teats) milked in a mid-line (LM) or low-line (LL) milking system

	ML	LL	*P*
BEFORE, mm	4·34 ± 0·02	4·41 ± 0·02	NS
AFTER, mm	4·51 ± 0·02	4·60 ± 0·02	NS
DIFFERENCE, mm	0·17 ± 0·03	0·19 ± 0·02	NS
PERCENTAGE,%	3·92 ± 0·62	4·31 ± 0·62	NS

NS = Not significant ($P > 0·05$)

Discussion

When milking in ML, average teat-end vacuum is reduced, mainly due to hydrostatic pressure exerted by the air and milk mixture as it rises up the long milk tube, and this fall is steeper the higher the milk flow (Le Du, 1977). In this paper, where nominal vacuum was set at 40 kpa in ML, a drop in average vacuum of almost 6·5 kPa was observed in milk flow conditions (average and peak flows around 0·6 l/min and 0·95 l/min, respectively), and about 3 kPa in the absence of flow at milking. This great difference in the average teat end vacuum conditions with and without flow (overmilking) shows the difficulty in defining the nominal vacuum in ML, and even more so as the animals' milk flow increases. Also, as expected, the teat-end vacuum fluctuations were higher in ML than in LL, in agreement with other reports (Le Du, 1977; Murgia & Pazzona, 1999; Díaz et al. 2004).

From studies in the bovine, we may conclude that it is unclear whether high cyclical teat-end vacuum fluctuations, such as those generated during ML milking, can cause an increased incidence of mastitis. Some authors (Billon et al. 1998) stated that high cyclical vacuum fluctuations could, by themselves, raise the risk of IMI, probably because they favour 'reverse flow', and thus increase teat exposure to bacteria as the milk flows from claw to teat. However, in some experiments carried out in the 1970s, it was found that the risk of mastitis increased only when high cyclic and acyclic fluctuations occurred simultaneously (Thiel et al. 1973). Recently Mein et al. (2004) indicated that bacteria can only penetrate and/or cross the teat canal when vacuum fluctuations generating an air speed against the teat of at least 6 m/s are created, and this situation could arise when there is a sudden influx of air into a teatcup, due to teatcup fall-off, liner slip, rough machine stripping or rough cluster removal. However, we must note that other researchers (Rasmussen et al. 1994) were only able to create fast air movement speeds, within the range cited, using experimental conditions (air inlets of 148 l/m than caused a vacuum drop of more than 40 kPa in less than 0·1 s) and not in conventional milking conditions. Besides, the cyclical teat-end vacuum fluctuation caused by the liner movement or vacuum changes in the milkline generate air speeds below 2 m/s, which would not be sufficient to enable bacteria to penetrate the teat canal (Mein et al. 2004). In any case, we must specify that when milking cows, the National Mastitis Council considers that, on average, the teat-end vacuum fluctuation should be lower than 7 kPa in LL and of 10 kPa in high line.

Table 4. Mean (±SE) of milk emission kinetics variables recorded in 54 goats milked in a mid-line (ML) or low-line (LL) milking system

		ML	LL	*P*
Milk volume, ml	Machine milk (MM)	989 ± 16	1062 ± 16	***
	Machine stripping milk (MSM)	97 ± 8	61 ± 8	**
	Total milk	1088 ± 15	1125 ± 15	NS
Milk flow, ml/min	First minute	610 ± 12	641 ± 12	NS ($P = 0·08$)
	Mean flow in MM	551 ± 9	580 ± 9	*
	Mean flow in MSM	259 ± 11	181 ± 11	***
	Maximum flow in MM	947 ± 14	937 ± 14	NS
	Maximum flow in MSM	405 ± 18	259 ± 18	***
	Time until maximum flow in MM	55 ± 3	67 ± 3	**
Milking time, s	MM time	118 ± 3	122 ± 3	NS
	MSM time	22 ± 2	16 ± 2	**
	Total milking time	140 ± 3	138 ± 3	NS

*$P < 0·05$; **$P < 0·01$; ***$P < 0·001$; NS = Not significant ($P > 0·05$)

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The results of this study, where ML presented higher cyclic teat-end vacuum fluctuations than LL, but without increasing significantly the rate of acyclic fluctuations (liner slip and teatcup fall-off) or affecting teat-end condition, seem to confirm that, at least in goat-milking conditions, the ML does not markedly increase mastitis risk in the long term, as mastitis incidence for the whole experiment was the same in ML and LL. However, we must emphasize that infections occurred earlier in the batch of animals milked in ML. Although these outcomes must be interpreted with caution, as the experiment was carried out with a small number of animals, one possible explanation would be based on the following hypotheses: (a) ML milking could slightly increase the risk of mastitis, especially in the animals most prone, leading to them becoming infected sooner; (b) it is possible that the risk of infection setting in throughout a lactation period depends to a greater extent on the susceptibility of each animal rather than tried and tested features of the milking machine-this would explain why at the end of lactation new infections tend to even out between the experimental groups milked in ML or LL.

The results of this experiment are consistent with the limited reports on this topic for small ruminants. Thus, two studies in sheep in experimental farm conditions agreed that ML did not increase SCC significantly (Le Du, 1985; Díaz et al. 2004), although in both cases these were short-term experiments. Moreover, Gonzalo et al. (2005), in field work, also failed to find any significant differences in SCC in tank milk on farms with ML compared with those with LL.

Changes in teat thickness after milking have been used as an indicator of teat tissue congestion/oedematization, which in turn could affect the susceptibility to mastitis and even serve as an indicator of the comfort level of animals during milking (Reinemann, 2007). Our results (around +4% teat thickness change) are in line with other work (+3·5%; Skapetas et al. 2008) and it would indicate that the machine milking induces a gentle teat tissue oedematization in goats. However, this oedematization, both in ML (+3·92%) and in LL (+4·31%) are inside the ±5% interval recommended in the bovine (Hamann et al. 1996).

Milkline height did not influence other relevant milking features either, such as total milk production and composition, or the total milking time for each animal, in agreement with that found by other authors in ovine livestock (Le Du, 1983; Díaz et al. 2004). However, the fact that ML tended to worsen the milk fractioning (significant differences only in the second experiment), is at odds with the findings of the two previously cited reports, as they found a similar milk fractioning in ML and LL.

ML reduced average machine milk fraction flow, which could be explained by the lower average teat-end vacuum. However, according to O'Callagan (2004) milk flow will depend mainly on the average teat end vacuum during phase B of pulsation. Although this variable was not recorded, from Fig. 1b it could be concluded that this vacuum would also be approximately 4 kPa lower in ML (around 34 kPa) compared with LL (around 37 kPa). On the other hand, it appears to be contradictory that ML should reduce the machine milk fraction flow rate, while increasing the flow of the machine stripping milk fraction. However, this result could be explained if we take into account that the volume of the latter fraction was also higher in ML, which would allow slightly higher flows, while also explaining why operators would have to spend more time to obtain this fraction. In any case, the results of the second experiment introduce a new unknown in terms of whether ML could affect total milk extracted and milking time when machine stripping is not carried out in the milking routine, as in those parlours that have automatic cluster removers.

Conclusions

In suitable milking conditions (machine and routine), ML does not seem to increase the risk of mastitis in the long term, although it must be emphasized that in our experiment the infections appeared sooner in ML than in LL. Nor did ML affect any other relevant milking features, such as the total milk yield and composition of total milk extracted, total milking time for each animal, or teat-end condition. ML affected the milk emission kinetics variables (average flow was reduced in machine milk fraction and was increased in machine stripping milk fraction) although, in practice, these results may be considered minor. To sum up, the differences found in this study between the ML and LL are not sufficiently important to merit advising goat farmers not to install ML, especially bearing in mind that this allows a lower initial investment and, moreover, facilitates the installation of automation in the milking parlour.

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