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Original article

Effect of variable traction on the teatcup during machine milking of ewes with or without hand stripping

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Summary — A system which exerts variable traction on teatcups has been designed so that the traction is strongest 35–40 s after the beginning of the milking. The system also makes it possible to reduce the bending of teats during machine milking. This system (traction system) was compared to normal milking (control system) using 62 Manchega ewes. After weaning (5 weeks), all the ewes were milked with the control system for 5 d (preexperimental) and then divided into 2 groups. Each milking system (control and traction) was assigned to each group at random, over a 10-week period (experimental). Milking occurred twice a day with machine and hand strippings until the fourth week of the experimental period (period 1), and then, hand stripping was omitted between weeks 5 to 10 (period 2) of the experimental period. The production and composition (fat and protein) of total milk did not present significant differences. The traction system tended to decrease residual milk while increasing its fat content; the differences were only significant with respect to fat content (15.7 *vs* 14.8%; $P < 0.05$). The traction system improved milk fractioning, increasing machine milk, although not significantly (+9%; $P = 0.09$), and decreasing machine stripping (–40%; $P < 0.001$) and hand stripping (–30%; $P < 0.001$). Moreover, this system also increased the milking time (12 s, $P < 0.001$). When hand stripping was omitted (period 2), the traction system tended to improve milk fractioning as compared with the control system, but total milk and fat yield barely varied (+1.7% and +5.9%, respectively; $P > 0.05$). The interaction "milking system by period" was not significant for any of the variables studied. The traction system increased teatcup falls (13.6 *vs* 7.7%; $P < 0.001$). It may also have had some effect on udder health as the somatic cell count increased, although not significantly ($P = 0.09$). The use of this system also resulted in more ewes (2 ewes *vs* no ewe with the control system) being culled as a consequence of acute mastitis. It can therefore be concluded that the traction system or simpler systems which exert more constant traction on the teatcups may only be interesting for milking routines without strippings (*eg* in rotary parlors with automatic cluster removers). New experiments need to be done to confirm whether these systems really affect the incidence of mastitis or if they inevitably produce a significant increase in teatcup falls.

machine milking / ewes / stripping / milking efficiency

Résumé — Effet d'un système qui génère une traction variable sur les gobelets durant la traite mécanique des brebis avec ou sans égouttage manuel. *Nous avons conçu un appareillage qui exerce une traction variable sur les gobelets (avec accroissement de la traction 35–40 s après le début de la traite) et qui permet de diminuer la torsion des trayons. Ce système (traction) a été comparé au système de traite traditionnel (témoin) sur un troupeau de 62 brebis Manchegas. Après le sevrage (5 sem) toutes les brebis sont traites avec le matériel témoin pendant 5 j (pre-expérimental) puis affectées au hasard pendant 10 sem soit au système «témoin» soit au système «traction». La traite a lieu 2 fois par jour avec égouttage machine et manuelle jusqu'à la 4e semaine (période 1) puis sans repasse manuelle entre la 5e et la 10e semaine (période 2) de traite. Si nous considérons l'ensemble de la période expérimentale, la production et la composition (taux butyreux et protéique) du lait total ne varient pas de façon significatives. Le système de traction a tendance à diminuer le lait résiduel et à augmenter son taux butyreux ; les différences sont seulement significatives pour le taux butyreux (15,7* vs *14,8%;* $p < 0,05$*). Le système de traction améliore le fractionnement : le lait-machine augmente (+9%, non significatif;* $p = 0,09$*), l'égouttage machine et la repasse manuelle diminuent (–40 et –30%, respectivement ;* $p < 0,001$*). En outre, ce système accroît le temps de traite (12 s;* $p < 0,001$*). Quand la repasse manuelle est supprimée (période 2), le système de traction a tendance à améliorer le fractionnement par rapport au système témoin, mais la production totale du lait et des matières grasses varie très peu (+1,7 et +5,9%, respectivement ;* $p > 0,05$*). L'interaction «Système de traite–Période» n'est significative pour aucune des variables étudiées. Le système de traction augmente les chutes des gobelets (13,6* vs *7,7% ;* $p < 0,001$*). Il pourrait aussi avoir un effet négatif sur l'état sanitaire de la mamelle car le nombre des cellules somatiques s'élève même si cette augmentation n'est pas significative (*$p = 0,09$*). En outre, dans ce groupe nous fûmes dans l'obligation d'éliminer 2 brebis affectées de mammites cliniques alors que ce ne fut pas le cas dans le groupe témoin. En conclusion, ce système de traction variable, ou un système plus simple qui exerce une traction plus constante sur les gobelets, pourraient être seulement intéressants dans le cas de routines de traite sans égouttage (par exemple manèges de traite avec dépose de gobelets automatique). De nouvelles expériences devront confirmer si ces systèmes ont réellement une incidence sur les mammites et s'ils induisent une augmentation de la chute des gobelets.*

traite mécanique / brebis / égouttage / efficacité de la traite

INTRODUCTION

At the end of the low flow period, the milk-flow stops, although some milk remains in the gland cistern because the connection between the udder and teat sinuses is closed. Cows can then be machine stripped usually by applying extra weight or traction to the teatcups. This stretches the tissues around the base of the teat, resulting in a partial, but temporary, re-opening of the milk passageway to teat sinus (Mein *et al,* 1973; Mein, 1992). In ewes, machine stripping is normally applied by vigorously massaging the udder for 6–10 s just before the teatcups are removed (Labussière, 1983). Intracisternal milk pressure is thus increased as more milk descends to the cistern, as a result of the compression by the hand in the cisternal area. In this way, additional milk can pass through the constriction produced at the teat base. While such machine stripping is quite efficient, obtaining 10–28% of the total milk production (Labussière, 1983), it unfortunately cannot be automated.

In a previous study on ewes, Peris *et al* (1995) used a short-term experiment to prove that the traction generated by springs on the teatcups improved milk fractioning, increasing machine milk by 16% and decreasing machine stripping and hand stripping by 60 and 26%, respectively. This result could be due to the downward pulling effects of the springs on the teatcups maintaining the connection between the gland and teat cistern open for longer (Mein, 1992). This effect could be similar to that described in cows with automated stripping devices (Dethlefsen *et al,* 1990; Hamann and Dodd, 1992). In the trial of Peris *et al* (1995), traction was also exerted to reduce teat bending, at it might produce pain and inhibit the ejection reflex (Labussière, 1988); this could explain the slight increase in milk yield (3.8%). Because hand stripping was carried out in this experiment, one could question whether, without this operation, a greater difference in milk yield would be apparent given the fact that when less milk is retained in the udder after milking, lower inhibition of the milk secretion should take place (Wilde and Knight, 1989). On the other hand, the traction exerted on the teatcups was relatively constant throughout the whole milking, except for a slight increase due to a decrease in the udder volume. Nevertheless, it would seem logical that traction should be variable: very weak for the first 30–40 s to avoid irritation or pain resulting in interference of the milk ejection (Dsyusembin, 1978; Goodman and Grosvenor, 1983), and relatively strong later, to empty the udder more effectively.

The aim of this study was to evaluate in ewes the effect of variable traction on the teatcups in a long-term experiment, with or without hand stripping.

MATERIALS AND METHODS

Description of the milking systems used

The 2 systems differed with respect to the position of the teatcups at milking:

Control system

The control system corresponded to the traditional milking system (see later), with the teatcups hanging from the teatcups in a more or less vertical position, due to the weight of the milking unit (approximately 0.4 kg). This induced bending of the teats because of their slanting position in the udder.

Traction system

The following accessories were included (fig 1):

1) A *piston* joined to the beginning of the short milk tube, and a plunger joined to a spring which was hooked, in turn, to a wire mesh.

2) A *spring*, which caused the traction on the teatcup and also allowed the angle of the teatcups to be adapted to reduce the bending of the teats. Both the traction and the angle of the teatcups were fixed at the beginning by means of a hitching point chosen on the wire mesh.

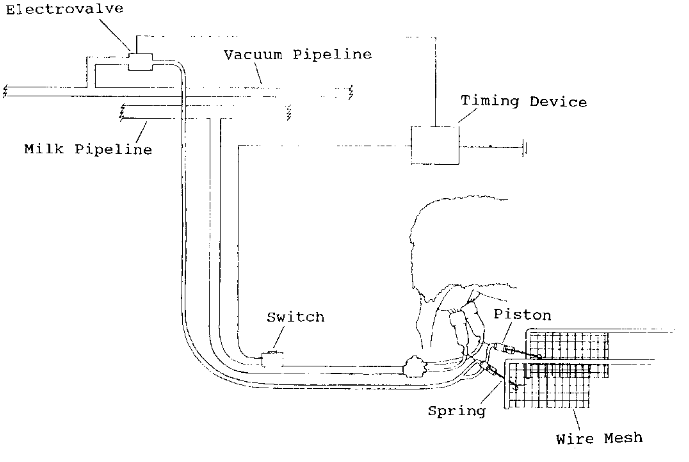

Fig 1. System designed to get a variable traction on the teatcups (traction system).

3) *Separators* connected to the feeding troughs limited the movement of the ewes and also had an adjoining wire mesh onto which the springs were hooked.

4) With the *switch-timing device-electrovalve system*, the electrovalve could open approximately 35–40 s after the teatcups had been attached, and the vacuum entered the piston, making the plunger move and increasing the traction exerted by the spring on the teatcup. The increase in the traction, measured with a dynamometer, resulted in a force of 630 *g* at each teatcup.

With this system, it was necessary to carry out 2 additional operations after attaching the teatcups: the springs were hooked onto the wire mesh, and the switch was turned on. Both operations took about 4–5 s.

The objective of this system was to reduce the possible pain caused by teat twisting (Labussière, 1988), and avoid strangulation of the teat base at the end of milking and thus allow a more effective emptying of the udder.

Experimental design

Sixty-two Manchega ewes from the experimental farm of the Polytechnic University of Valencia were used. After weaning (5 weeks), the ewes were machine milked twice daily for a preexperimental period of 5 d, during which all the animals were milked with the control milking system. They were then divided into 2 groups taking into account production, milk fractioning, teatcup falls and morphological characteristics of the udder (table I) which had been recorded for the last 3 d of the preexperimental period. Each of the groups was assigned 1 of the 2 methods (control or traction) at random, for the whole experimental period (10 weeks). Only 60 ewes were considered in the results (preexperimental and experimental periods) because 2 ewes from the spring group were eliminated in the second week of the experimental period due to acute mastitis.

Milking equipment and method

A high line Casse-type milking parlor was used (2 x 12 x 6), with the following parameters: vacuum = 44 KPa, pulsation rate = 120 p/m, pulsation ratio = 50%. The milking unit was made up of a synthetic rubber liner (Alfalaval n° 961402-01, mouth diameter: 18.5 mm), a metal shell (Alfalaval n° 960153-80) and a claw with air admission (Alfalaval n° 961410-80). The weight of the

Table I. Milk production, udder morphology and teatcup falls in the preexperimental period.

Variable	*Group A* [a] *(n = 31)* *m (SE)*	*Group B* [b] *(n = 29)* *m (SE)*
Milk production [c]		
Machine milk, ml/d	962 (39)	974 (38)
Machine stripping, ml/d	158 (12)	164 (14)
Hand stripping, ml/d	168 (11)	182 (16)
Total milk, ml/d	1 287 (41)	1 320 (44)
Udder morphology		
Teat angle, degrees [d]	44.3 (1.8)	44.7 (1.8)
Cistern height, mm [e]	10.2 (1.7)	9.8 (1.7)
Teat diameter, mm [f]	16.3 (0.4)	16.1 (0.4)
Teat length, mm	36.4 (2.1)	35.6 (1.4)
Teat falls (%)	20.6	17.9

[a] Group milked with the control system in the experimental period; [b] Group milked with the traction system in the experimental period; [c] recorded during 3 consecutive days; [d] from vertical; [e] distance between teat base and lower part of the cistern; [f] measurement at the middle.

installed milking unit was approximately 400 g. Ewes were machine milked twice daily at 08.00 and 17.30 with the complete routine (machine and hand stripping included) during the preexperimental period and during the first 4 weeks of the experimental period (period 1). During the following 6 weeks (period 2), hand stripping was omitted in both milking groups. Machine stripping was a vigourous udder massage for 6 to 10 s before the teatcups were removed.

Variables measured

All the variables cited here, except the residual milk and milking time, were measured at weekly intervals in the fractions detailed in table II. The variables were as follows:

– Production of the following fractions: machine milk obtained from when the teatcups were attached until the milk flow stopped; machine stripping milk obtained during the machine stripping operation; hand stripping obtained after removing the teatcups. During period 1 (weeks 1 to 4 of the experimental period), the total milk production was calculated as the sum of the 3 fractions mentioned. During period 2 (weeks 5 to 10 of the experimental period), the total milk production was calculated as the sum of the machine milk and machine stripping milk fractions. Although in period 2 hand stripping was omitted, the control of this fraction (only 1 d per week) was continued, but the control corresponding to the morning milking was carried out 2 d before the rest of the variables were recorded, so as not to interfere with the afternoon control.

– Residual milk was determined for the evening milking during the weeks 1, 2, 4, 5, 7 and 9 of the experimental period. After milking (including hand stripping), each ewe was injected with 2 UI of oxytocin and residual milk was obtained manually 1 min later.

– Composition (fat and protein) was determined by an near infrared instrument (Infraanalyzer D400, Brann & Luebbe, Nordejtedt, Germany), except for low volume samples (< 30 ml) where only Gerber fat was analysed. Likewise, for hand stripping and residual milk fractions, only fat content was determined.

Table II. Variables measured in the experimental period.

a) Period 1 (weeks 1–4)

Week day	*Production*	*Composition*	*SCC*	*Falls*
Thurs morning	MM, MS, HS	MM+ MS+ HS	MM+ MS+ HS	Yes
Thurs afternoon	MM, MS, HS, RM	MM+ MS+ HS, RM	–	Yes

b) Period 2 (weeks 5–10; without hand stripping)

Week day	*Production*	*Composition*	*SCC*	*Falls*
Tues morning	HS	HS	–	–
Thurs morning	MM, MS	MM+ MS	MM+ MS	Yes
Thurs afternoon	MM, MS, HS, RM	MM+ MS, HS, RM	–	Yes

MM = machine milk fraction; MS = machine stripping fraction; HS = hand and stripping fraction; RM = residual milk; SCC = somatic cell count.

– Milking time was measured for the morning milking during weeks 4 and 7 of the experimental period, and repeated 2 d a week. The manual method described by Ricordeau *et al* (1963) was utilized, but the milk flow was recorded every 5 s. The milking was considered finished when the milk flow was lower than 5 ml/5 s.

– The incidence of teatcup falls was recorded with the same frequency as production. The milkers recorded whether the teatcup fell by itself (passive falls) or if the fall was due to active animal participation (kicks, brusque movement).

– The udder health was determined with the somatic cell count (SCC), using a Fossomatic-90 (Foss Electric, Hillerod, Denmark), in the total milk production from the morning milking.

Statistical analysis

The composition, residual milk, SCC in log and milking time were analysed as a "repeated measure study", with the following model:

$$Yijk = m + Si + Ej(Si) + Pk + SixPk + eijk$$

where m = general mean; Si = milking system effect; $Ej(Si)$ = effect of ewe j nested within milking system i; Pk = period effect; $k = 1$, period with hand stripping (average of weeks 1 to 4); $k = 2$, period without hand stripping (average of weeks 5 to 10); $SixPk$ = interaction milking system by period; $eijk$ = residual (interaction ewe by period).

The milking system effect was tested using ewe within milking system as the error term. When the interaction of the milking system by period was not significant, the period effect was substituted by the week effect. Fractioning and total milk production data were analysed using means from the preexperimental period as covariates in the above model. For the statistical analysis, the general linear models procedure of the SAS, version 6.0 (SAS Institute, Inc, Cary, NC, USA) was used with results expressed as least squares means. The frequency of teatcup falls was analysed by chi-square analysis.

RESULTS

The results of analysis of variance are shown in table III. In the overall experimental period (weeks 1–10), the production and composition (fat, protein) of total milk did not vary significantly. Residual milk did not change significantly in production, although its fat percentage was slightly higher (15.7 *vs* 14.8%; $P < 0.05$) with the traction system. The traction system improved the milk fractioning, by increasing machine milk (875 *vs* 802 ml; + 9%) although not significantly at a level of 95% ($P = 0.09$), and significantly reducing ($P < 0.001$) machine stripping (74 *vs* 125 ml; –40%) and hand stripping (67 *vs* 97 ml; –30%) fractions. The fat content of the hand stripping fraction (in period 2) was also higher with the traction system (14.8 *vs* 14.0%; $P < 0.01$). Finally, the milking time in this group was longer, averaging 12 s (49 *vs* 61 s; $P < 0.001$).

The interaction "milking system by period" was not significant for any variable studied. Nevertheless, for some variables, the differences between milking systems tended to be higher after hand stripping was eliminated (table III, fig 2). The differences between the traction and the control system in period 1 and 2 were, respectively: machine milk, +62 and +77 ml; machine stripping, –40 and –58 ml; total milk, –9 and +15 ml; fat, in percentage, 0 and +0.2 points; fat, g/d, +1 and +4 g/d. Only with the machine stripping and fat content variables did the interaction "milking system by period" approach a significant level of 95% ($P = 0.07$).

The SCC, in log, tended to be higher with the traction system, especially at the beginning of the milking period (table III, fig 3), although the differences were not statistically significant ($P = 0.09$). In addition, 2 ewes from the traction group were removed from the trial in the second week because of being infected with acute clinical mastitis, whereas none of the control group animals were eliminated.

Teatcup falls were also higher with the traction group (13.6 *vs* 7.7%; $P < 0.001$; table IV). This was due to passive falls

Table III. Least square means of various milking variables by milking system and period.

Variable	Period 1 (with hand stripping weeks 1–4)			Period 2 (without hand stripping weeks 5–10)			Total period (weeks 1–10)			
	Control	*Traction*	*SE*	*Control*	*Traction*	*SE*	*Control*	*Traction*	*SE*	*Sig lev*
Milk production										
Machine milk (ml/d)	914	976	32	729	806	33	802	875	31	NS
Machine strip (ml)	130	90	6	121	63	7	125	74	6	***
Hand strip (ml) [a]	110	82	5	89	57	5	97	67	4	***
Total milk (ml) [b]	1 156	1 147	29	852	867	33	973	980	29	NS
Residual milk (ml)	130	109	12	92	71	9	113	90	10	NS
Milk composition										
Total milk [b]										
Fat (%)	7.3	7.3	0.1	8.1	8.3	0.1	7.8	7.9	0.1	NS
Fat (g/d)	82	83	3	68	72	4	74	77	3	NS
Prot (%)	5.3	5.2	0.1	6.1	5.9	0.1	5.8	5.6	0.1	NS
Hand stripping										
Fat (%)				14.0	14.8	0.2				**
Residual milk										
Fat (%)	14.5	15.4	0.4	15.0	16.0	0.3	14.8	15.7	0.3	*
Milking time (s)	49	60	2	49	62	2	49	61	1	***
SCC, cells/ml (log)	5.03	5.18	0.04	5.13	5.19	0.03	5.08	5.19	0.04	NS
SCC, cells/ml (x 10^3) [c]	107	151		134	156		122	154		

[a] Hand stripping was controlled 1 day per week during the period without hand stripping at milking; [b] sum of machine milk, machine stripping and hand stripping (weeks 1–4) or sum of machine milk and machine stripping (weeks 5–10); [c] geometric mean. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. SCC = somatic cell count; Sig lev = significance level.

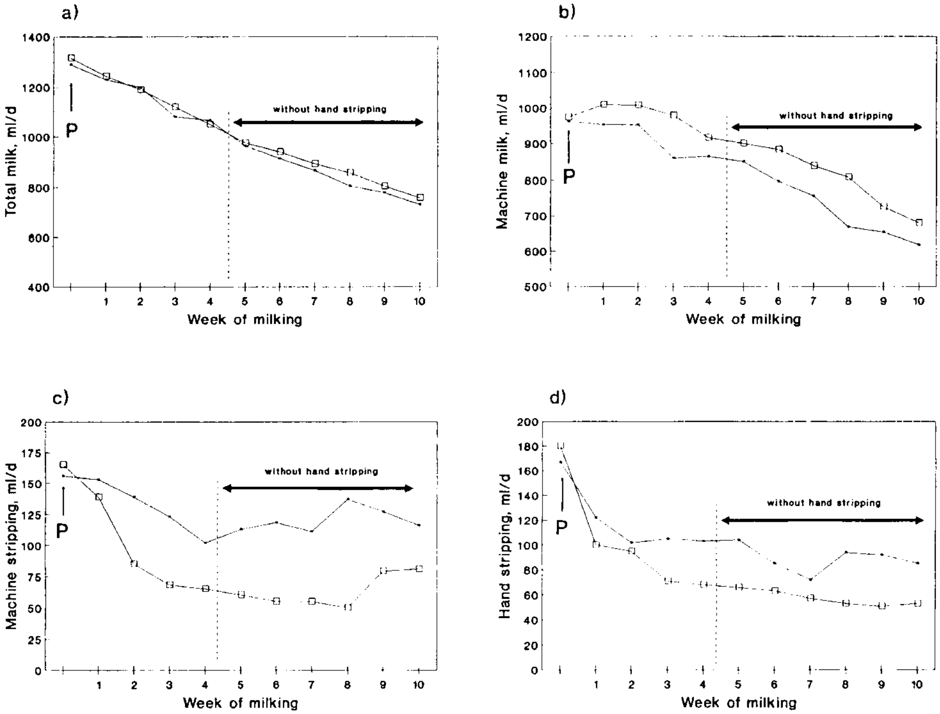

Fig 2. Weekly evolution of a) total milk; b) machine milk; c) machine stripping and d) hand stripping fractions according to the milking system used: – – – Control system (n = 31 ewes); –□–□– traction system (n = 29 ewes). Machine milking began after the lambs were weaned (5 weeks of suckling). After the fourth week, hand stripping was omitted, although once a week was recorded. P : preexperimental period (mean of 3 days).

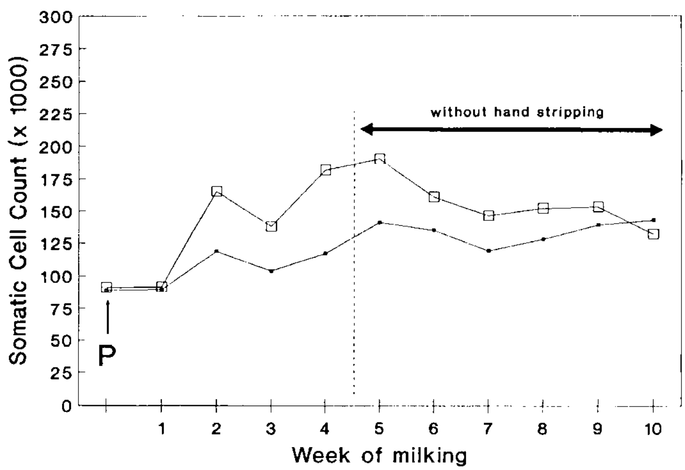

Fig 3. Weekly evolution of the somatic cell count (geometric mean) in the total milk of the morning milking according to the milking system used: – – – control system (n = 31 ewes); –□–□– traction system (n = 29 ewes). Machine milking began after the lambs were weaned (5 weeks of suckling). After the fourth week, hand stripping was omitted. P: preexperimental period.

Table IV. Teatcup falls during 10 weeks of machine milking, according to the milking system used. Falls were recorded 1 day of each week.

Milking system	*N*	*No falls*	*Passive falls* [a]		*Active falls* [b]		*Total falls*	
		%	%	χ	%	χ	%	χ
Control	620	92.3	3.6	***	4.1	NS	7.7	***
Spring	580	86.4	8.4		5.2		13.6	

[a] Produced by liner slipping; [b] produced by the ewe (kicks, brusque movements); χ : chi-square test; *** $P < 0.01$.

(8.4 *vs* 3.6%; $P < 0.001$), while the falls produced by the ewe (kicks, brusque movement) were similar in the 2 groups (4.1 *vs* 5.2%; $P > 0.05$). During the first 2 weeks of milking, the number of falls was similar as well as high in both groups (10–20%; fig 4). This is due to the fact that the animals had not yet adapted to machine milking (Labussière, 1988). Later, the number of falls decreased in the control group to a relatively constant level for the remaining milking period (5–8%), whereas in the traction group this decrease did not occur.

DISCUSSION

The better milk fractioning obtained in this experiment with the traction system confirms the previous results of Peris *et al* (1995). The 9% increase in the machine milk fraction could be due to the traction exerted on the teats, which allowed the communication between gland and teat cisterns to remain open for a longer period of time (Mein *et al*, 1973); this would also explain why the milking time increased by 12 s. Although both

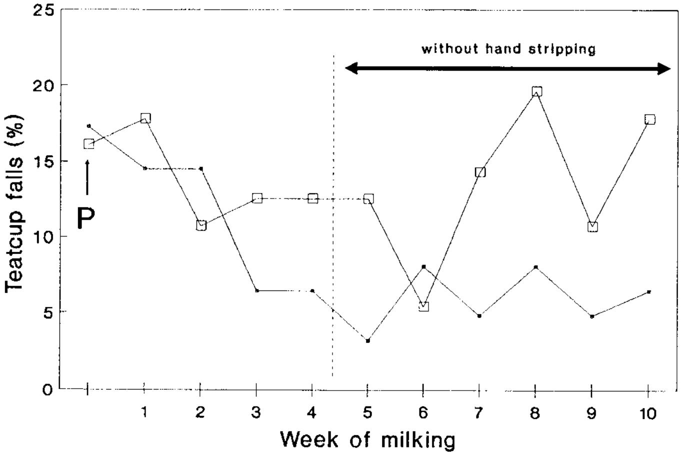

Fig 4. Weekly evolution of teatcup falls (%) according to the milking system used: –·–·– control system ($n = 31$ ewes); –□–□– traction system ($n = 29$ ewes). Falls were recorded 1 day for each week. Machine milking began after the lambs were weaned (5 weeks of suckling). After the fourth week, hand stripping was omitted. P: preexperimental period.

machine and hand strippings decreased with the traction system, it is important to note that the first fraction did so to a greater extent (–51 and –30 ml for machine and hand stripping, respectively). Furthermore, the higher fat content of the hand stripping fraction also confirms that, after removal of the teatcups, the traction system left less milk in the udder than the control system.

On the other hand, the designed system, which exerted a greater traction 35–40 s after teatcup attachment, did not improve the fractioning obtained with simple springs which exerted a relatively constant traction (Peris *et al,* 1995). Expressed in percentage of total milk, the machine milk, machine stripping and hand stripping obtained in this experiment are, respectively, 85, 8 and 7% (period 1), whereas in the previously cited experiment they were 89, 4 and 7%. This last result could be explained because, in fact, the springs increased traction slightly throughout the milking as the size of the udder reduced.

In contrast with the results obtained by Peris *et al* (1995), production and composition of the total milk extracted did not significantly differ between the traction and control groups. The differences in residual milk (only significant in fat percentage) could be explained by 2 possible causes. First, the 2 groups might have already presented these differences during the preexperimental period. Second, as the traction system also reduced teat twisting during the milking, it may favour the ejection reflex. In fact, Labussière (Labussière *et al,* 1981; Labussière, 1988) hypothesized that in ewes with a teat angle far from vertical, pain is suffered as a result of the teat base being twisted by the cluster weight, and this pain could inhibit the ejection reflex. Nevertheless, given the fact that the total milk removed at the milking did not vary with respect to the control system, the first explanation could seem, in this case, more probable.

The results obtained when hand stripping is omitted from the milking routine (period 2) are not satisfactory enough to justify the use of the traction system because the milk and fat yield barely increased (+1.7 and +5.9%, respectively) and the teatcup falls increased.

Teatcup falls with the traction system (13.6%) were much higher than those observed by Peris *et al* (1995) with a relatively constant traction (6.6%). This could be because traction at the teatcups increased suddenly when the piston moved. It would be interesting to know if it would be possible to keep a good fractioning with fewer teatcup falls with less traction (*eg* 400– 500 g) utilizing a short piston or a more flexible spring. In any case, this result agrees with that of Le Du *et al* (1978), who, on comparing different types of liners, concluded that systems favouring better fractioning tend to produce a higher number of falls. This also occurs when the cluster weight is increased in cows (Mein, 1992).

The traction system might have affected the udder health negatively, although there was no significant evidence for this considering the limited differences in the SCC (not significant) and milk yield. Moreover, in machine milking of cows, the general question of the influence of automatic machine stripping on udder health also seems to be open (Hamann, 1989). If we accept that the traction system tended to augment the incidence of mastitis, there could be 2 causes. First, traction could increase liner slips, thus favouring "impact" and mastitis infection (O'Shea *et al,* 1987). This would be similar to the effect of increased cluster weight, which produces a higher liner slip and fall-offs in cows (O'Shea *et al,* 1983). Second, the traction on the teats could negatively affect teat condition (congestion, oedema, teat canal integrity), which could also favour mastitis infection (Hamann, 1987; Zecconi *et al,* 1992).

CONCLUSION

The designed system which exerted a variable traction on the teatcups during milking, improved milking fractioning as machine milk tended to increase and strippings diminish. Nevertheless, this fractioning was not significantly better than that obtained with a simpler system that exerted a more constant traction during milking.

These systems are not interesting, in practice, for milking routines that include machine stripping (with or without hand stripping), as the milk and fat yield barely increase. However, they could be useful for milking flocks when all types of strippings are dispensed with, as in rotary milking parlours fitted with automatic detachers, because they give increased yields of machine milk (9% in this experiment). For this type of milking installation, it would be possible to design a simple, totally automated traction system, thereby reducing the milker's routine of attaching the milking cluster. Further large-scale research is required to discover whether traction affects liner slips, mastitis and if, inevitably, the teatcup falls increase.

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