Original article

Comparison of different machine milking clusters on dairy ewes with large size teats

N Fernández *, R Requena, MC Beltran, C Peris, M Rodríguez, P Molina, A Torres

Department of Animal Science, Polytechnical University of Valencia, Camino de Vera 14, 46071 Valencia, Spain

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Summary — Sixty-five Manchega ewes were milked with three different commercial clusters with different teatcup and claw characteristics. Clusters with a lip mouthpiece deflection close to 20 mm/kg (vs 8 mm/kg) increased the amount of machine milk (7.6–11.5%) and reduced the hand stripped milk (22.7–40.5%) and residual milk volumes (9.7–14.9%). They also improved the milk fat (2.3–2.5%), lactose (1.0-1.4%) and dry matter (1.8%) composition, thereby potentially simplifying the machine milking routine. Milk flow was improved by large claws (91–140 mL vs 48 mL) in a milking parlour where the pipeline was placed above the platforms. Teatcup falls were related to a liner mouthpiece with a bore greater than 17 mm and to a heavy shell + liner + short milk and pulse tubes (224 g vs 156–168 g). The combined low weight of these permitted a reduction in vacuum level, thus decreasing the risk of mastitis. The claw's weight (89–201 g) had no influence on teatcup falls because it hung from a band. The final conclusion was that teat size determined the optimal type of liner. Thus, a mouthpiece bore of 17 mm was better for teats up to 45 mm long or 20 mm wide, while a bore of 19 mm was preferable for bigger teats.

machine milking / ewe / cluster / milking efficiency

Résumé — Comparaison de différents faisceaux-trayeurs dans la traite mécanique de brebis avec de grands trayons. À l'origine, les machines à traire furent conçues pour la brebis Lacaune, dont le trayon est plus étroit que celui de la plupart des races ovines européennes. Une adaptation de la machine aux caractéristiques de certaines races pourrait donc se révéler nécessaire. Dans ce travail, 65 brebis de race Manchega ont été divisées en trois groupes et soumises à la traite avec trois faisceaux-trayeurs de marques commerciales différentes, pendant 6 semaines, en utilisant un schéma en carré latin (3 × 3). Les faisceaux-trayeurs différaient par les caractéristiques du corps du manchon (longueur, pression de flambage) et de l'embouchure (diamètre, souplesse des lèvres) mais aussi par le poids du faisceau-trayeur, la taille et le dessin de la griffe. Une souplesse des lèvres de près de 20 mm/kg (vs 8 mm/kg) augmente le lait machine (8–11 %) et réduit la repasse (23–41%) ainsi que le lait rési-

* Correspondence and reprints

duel (10–15%). Elle améliore la composition du lait, augmente le taux butyreux (2,3–2,5%), la teneur en lactose (1,0–1,4%) et en matière sèche (1,8 %), et fait entrevoir la possibilité d'une traite simplifiée (sans repasse). L'emploi de griffes de grande taille (91–140 vs 48 mL) facilite le transfert du lait vers le récipient de contrôle (lactoduc en ligne haute). Le décrochage des faisceaux-trayeurs est plus aisé lorsque le diamètre de l'embouchure est supérieur à 17 mm, et lorsque le poids de l'ensemble gobelet + manchon + courts tuyaux à lait et de pulsation est élevé (224 vs 156–168 g). Un poids inférieur à cet ensemble permettrait de réduire le degré de vide de traite et, par là, le risque de mammite. En revanche, le poids de la griffe (89–201 g) ne semble pas avoir d'influence, car elle est suspendue à une courroie qui en réduit l'effet. En conclusion, la taille du trayon détermine le modèle optimal du manchon, et il apparaît qu'un diamètre d'embouchure de 17 mm s'adapte mieux aux trayons ayant moins de 45 mm de long et/ou 20 mm de large, tandis qu'une embouchure de 19 mm est préférable pour de plus grands trayons.

traite mécanique / brebis / faisceau-trayeur / efficacité de la traite

INTRODUCTION

In comparison with dairy cattle, there are many more dairy sheep breeds used in commercial milk production. The sheep breeds differ in udder conformation and this makes the development of optimal mechanical milking equipment more difficult.

With machine milked sheep, a relatively large proportion of the yield is obtained as stripping milk (Labussière, 1988) and in milking parlours this can result in a 42% reduction in the number of animals milked per hour (Fernández et al, 1989).

Some machine milking problems are actually due to the fact that the design is based on Lacaune breed characteristics. This breed has narrower (15 mm) teats than Churra (16 mm), Karagouniko (21 mm), Manchega (19 mm), Sarda (17 mm), Serra da Estrela (17 mm) and Tsigay (17 mm) breeds (Labussière, 1988). Such et al (1989) showed that ewes with bigger teats produced greater quantities of stripping milk than the others.

One of the factors affecting milking performance is the liner design, and different authors have demonstrated this by changing the liner mouthpiece characteristics (Le Du, 1978; Such et al, 1989), using liners made with different materials (Le Du, 1982), comparing old and new liners (Le Du and Taverna, 1989a) or by varying the rough inner barrel (Le Du and Taverna, 1989b). Similarly, Peris et al (1989) demonstrated the influence of liner mouthpiece design on the volume of the different fractions of milk obtained in machine milking, although some of the models which reduced stripping fractions through a wider mouthpiece bore caused an increase in teatcup falls.

The present work studied the effectiveness of new commercial clusters, whose design takes into account some of the details which could improve the milking of ewes with large teats.

MATERIALS AND METHODS

Ewes

Sixty-five Manchega ewes, from the Polytechnical University of Valencia (Spain), were subjected to a suckling + milking (morning) system for a period of 5 weeks after lambing, followed by exclusive milking (morning + evening milkings) until the end of the lactation. They were classified, by lactation number and yield to lactation day 55, into three groups (table I).

After the experiment, the ewes were classified according to their teat length and width (table V).

Milking

The ewes were milked in a milking parlour with six clusters and the milk pipeline and recording container entrance were 1.0 m and 0.9 m, respec-

Table I. Characteristics of the ewes used in a Latin square experiment on day 55 of lactation. DMP, daily milk production (MM + MS + HS); MM, machine milk; MS, machine stripping milk; HS, hand stripping milk; RM, residual milk; TP, total protein; L, teat length; W_1, teat width at the base; W_2, teat width at the central section; α, teat angle; N, teat position.

Experimental group	*Lactation number*		*DMP (mL)*	*Milk fractioning (mL)*			*RM (mL)*	*Milk composition (%)*		*Udder morphology*				
	1st	*>1st*		*MM*	*MS*	*HS*		*Fat*	*TP*	*L (mm)*	*W1 (mm)*	*W2 (mm)*	*α (°)*	*N* [a] *(1–5)*
1	4	17	1385	1052	163	170	147	7.1	5.2	41.4	20.6	16.5	41.3	2.9
2	5	17	1274	956	164	154	134	7.3	5.3	37.8	19.7	16.2	43.7	3.1
3	5	17	1273	967	163	143	133	7.5	5.4	36.3	18.8	15.7	44.1	3.3
Mean	14	51	1310	992	163	157	139	7.4	5.3	38.4	19.7	16.1	43.1	3.1
±			±	±	±	±	±	±	±	±	±	±	±	±
ES			16	33	6	5	7	0.4	0.3	1.4	0.7	0.6	1.6	0.1

[a] $N = 1$ characterizes the teats placed at the rear, and $N = 5$ is given to those situated towards the front

tively, above the platforms . The recording containers were located between the long milk tubes and the milk pipeline throughout the experiment. The vacuum level was 42 kPa, the pulsation rate 120/min and the pulsator ratio 50%. Three different types of commercial clusters were tested and their major characteristics are presented in table II and figures 1 and 2. Most of the barrel measurements were taken from plaster moulds (JL Ponce de León, personal communication). The lip mouthpiece deflection corresponded to the descending value of the lip when a 0.5 kg weight was applied to a stopper closing the mouthpiece bore (O'Shea et al, 1983). Barrel rigidity was determined from the minimum necessary vacuum, applied to the liner end, needed to close the barrel within the shell (Le Du et al, 1978). The liners from the A and C clusters were integral (the liner and short milk tube formed a single element).

Table II. Characteristics of the three commercial clusters used for the milking of ewes with large size teats in a Latin square experiment.

Characteristics	*No fig 1*	*Cluster*		
		A	*B*	*C*
Cluster				
Total weight (g)		313	312	357
Claw				
Weight (g)		89	144	201
Volume (mL)		48	140	91
Rigid shell				
Weight (g)		99	30	27
Liner [a]				
Weight (g)		82 [d]	36	86 [d]
Mouthpiece				
External width (mm)	1	39	43	47
Bore (mm)	2	18	17	19
Lip				
Length (mm)	3	7	8	9
Thickness (mm)	4	3	2	2
Deflection [b] (mm/kg)		8	22	20
Cavity				
Height (mm)	5	8	8	14
Volume (mL)	6	4	6	12
Barrel				
Bore at the top of the barrel (mm)	7	20	19	18
Bore at the bottom of the barrel (mm)	8	16	17	17
Length (mm)	9	94	97	94
Volume (mL)	10	26	27	27
Rigidity: tightening vacuum compression [c] (kPa)		10	9	8
Minimum bore at the end of the liner (mm)	11	9	10	8

[a] Measurements of the liner were taken with a plaster mould (JL Ponce de León, personal communication). [b] According to O'Shea et al (1983): descending value of the lip on application of 0.5 kg weight to a stopper closing the mouthpiece bore. [c] According to Le Du (1978): minimum necessary vacuum to close liner barrel within shell. [d] Integral (liner + short milk tube).

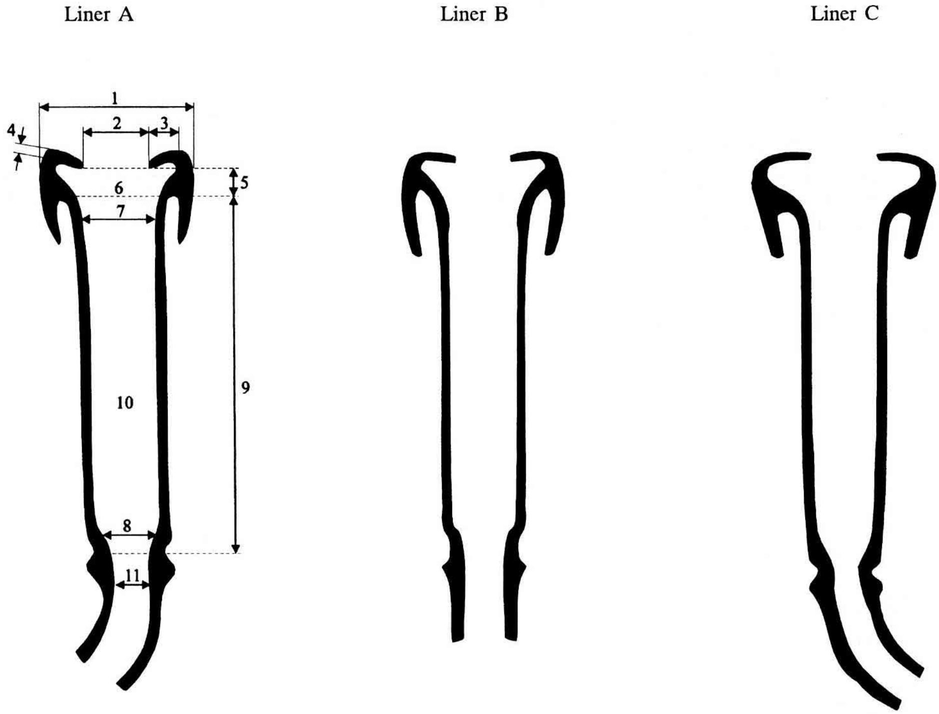

Fig 1. Liner section.

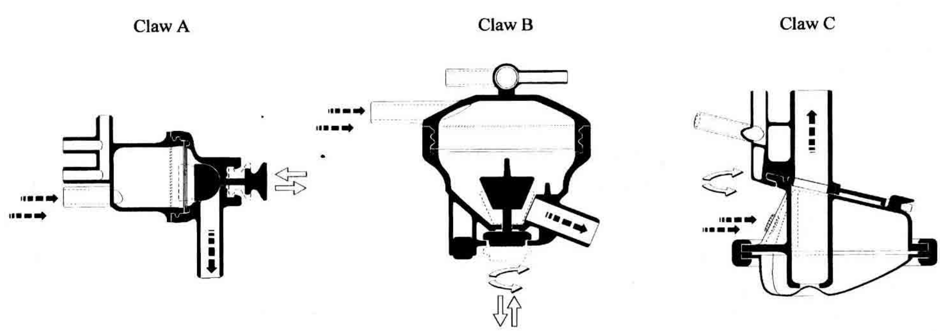

Fig 2. Claw design. White arrows represent opening and closing vacuum system; black broken arrows represent milk flow.

At each milking, separate measurements were made of the milk yield obtained by the milking machine unaided (MM), the yields of machine strippings when there was vigorous udder massage (MS), and finally the hand strippings which started 1 min after the teatcups were detached and any milk left in the udder removed (HS).

Experimental design

Each group was milked with each cluster for a period of 2 weeks, following a Latin square design (3 × 3) for 6 weeks, starting the 9th week after lambing, when all the animals had become accustomed to machine milking (4th week after weaning).

Twice a week (Tuesdays and Thursdays) morning and evening milk yields (MM + MS + HS) and composition, milk fractioning (MM, MS, HS), somatic cell count and the incidence of falls were recorded. Milk composition (fat, total protein, true protein, lactose and dry matter content) was measured using an infra-red analyser (D400 Bran+Luebbe, Werkstrasse 4, 22844 Hamburg, Germany), and the somatic cell count with a Fossomatic 90 (Foss Electric; DK-3400 Hillerød, Denmark). Teatcup falls were recorded as follows: no falls, 0; 1, fall produced by the liner slipping (passive falls); 2, due to an unexpected movement by the ewe (active falls). On Thursdays, after the evening milking, the residual milk (RM) was obtained manually after injecting 2 IU oxytocin into the jugular.

Morphology of the udder

Before starting the experiment the udder characteristics (L, teat length; W_1, teat width at the base; W_2, teat width at the central section; α, implantation angle; N, teat position) were measured independently (Labussière, 1984) by two assistants. The average values of these measurements are presented in table I.

Kinetic milk emission

Kinetic milk emission was used to evaluate the effect of the claw and cluster on milking time, milk extraction and evacuation to the recording containers placed above the platforms. Records of kinetic milk emission of the machine milking (Labussière, 1984) were taken from a group of 24 ewes belonging to the two peak class once the experiment had finished. A manual method of measuring was used; a strip of graph paper was attached to the outside of the recording container and the milk levels were recorded every 5 s. The kinetic characteristics were taken from these records: V1, volume of the first peak; V2, volume of the second peak; MF1, maximum milk flow of the first peak; MF2, maximum milk flow of the second peak; Fm, average flow of both first and second peaks; D, time lapsed before the second peak appeared; time for the maximum flow of the first peak; time for the maximum flow of the second peak; T, total time. Every day a different cluster (A, B or C) was utilized and, in addition, a kinetic was also taken from a combination of liner A and claws B (A+B) or C (A+C) in order to determine the significance of claw size on milk flow.

Statistical analysis

The statistical model employed was as follows:

$$Y_{ijklm}, \mu + \alpha_i + \beta_j + \gamma_k (\beta_j) + \delta_l + \varepsilon_{ijklm}$$

where: Y_{ijklm} = variable studied (total milk production, milk fractioning, milk composition, kinetic of emission and the log of the somatic cell count); μ, general mean; α_i, effect of the ewe; β_j, effect of the period; $\gamma_k (\beta_j)$, effect of the day, within the period; δ_l, effect of the milking cluster and ε_{ijklm}, residual.

Total milk production and milk fractioning data were also analysed after classifying the ewes into three groups, according to their teat lengths. This analysis was repeated after reclassifying the ewes into three groups according to their teat width. To analyse the statistical significance of the interaction between teat size group × milking cluster the model was:

$$Y_{ijklm} = \mu + \lambda_i + \alpha_j (\lambda_i) + \beta_k + \gamma_j (\beta_k) + \delta_l + \lambda_i \times \delta_l + \varepsilon_{ijklm}$$

where: Y_{ijklm}, variable studied (total milk production and milk fractioning); μ, general mean; λ_i, effect of the teat size group (length or width); $\alpha_j (\lambda_i)$, effect of the ewe, within the teat size group; β_k, effect of the period; $\gamma_l (\beta_k)$, effect of the day, within the period; δ_l, effect of the milking cluster; $\lambda_i \times \delta_l$, interaction between teat size group and milking cluster and ε_{ijklm}, residual.

The general linear model (GLM) procedure (SAS, 1989) was used with results expressed as least squares means. Student's *t*-test was utilized to assess differences between means. The frequence of teatcup falls was analysed comparing, two by two, the three clusters, with the chi-squared analysis. The relationship between variables of udder morphology and milking fractions was carried out following the SAS Corr procedure.

RESULTS

Milk yield and milk fractioning

The results presented in table III indicate that the average daily milk production (DMP) and machine stripping milk (MS) did not vary significantly between clusters. Nevertheless, the machine milk (MM) volume was higher and the hand stripping (HS) volume lower for cluster C than for clusters B and A. With respect to cluster A, the use of clusters C and B increased the MM by 11.5% and 7.6%, reduced the HS by 40.5% and 22.7%, and also reduced the residual milk by 14.9% and 9.7%, respectively.

Relationship between morphology of the udder and milk fractioning

The relationship between udder morphology and milk fractions for all the ewes and all the clusters was studied using correlation coefficients.

The most important relationships established were between the different parameters of the udder (table IV). Thus, longer (L) teats tend to be wider (W) and had a lower implantation angle (α), with a tendency to present a lower position index (N). Teats with higher α had a higher N.

Ewes with longer and wider teats gave both a higher daily milk and hand stripping milk production.

Interactions between cluster and teat length groups, and cluster and teat width groups were significant for MM ($P < 0.05$) and HS ($P < 0.01$ and 0.005, respectively), but not for daily milk production, MS or RM.

Machine milk production increased (table V) with the use of cluster C compared to either cluster B or cluster A. This was true for both very long teats (L > 45 mm) or very

Table III. Mean milk yields and milk fractioning (ml) of ewes with large size teats milked with three different clusters in a Latin square experiment. DMP, daily milk production (MM + MS + HS); MM, machine milk; MS, machine stripping milk; HS, hand stripping milk; RM, residual milk. Values are least square means ± SE and percentage of DMP or of evening milking.

Cluster	*Milk fraction*				
	DMP	*MM (%)*	*MS (%)*	*HS (%)*	*RM (%)*
A	1197 ± 8	860[c] ± 8 (71.9)	152 ± 4 (12.7)	185[a] ± 4 (15.4)	134[a] ± 5 (22.5)
B	1211 ± 8	925[b] ± 8 (76.4)	143 ± 4 (11.8)	143[b] ± 4 (11.8)	121[b] ± 5 (20.2)
C	1219 ± 8	958[a] ± 8 (78.6)	151 ± 4 (12.4)	110[c] ± 4 (9.0)	114[b] ± 5 (19.3)
Significant difference: $P <$	NS	0.001	NS	0.001	0.01

[a,b,c] Least squares means in a column with different superscripts differ ($P < 0.05$).

wide teats (W > 20 mm). With cluster C, less HS milk was obtained than with cluster B and with B less than with A in the case of ewes with very long, very wide, or even medium (L = 35–45 mm; W = 18–20 mm), or small sized teats (L < 35 mm).

Table IV. Correlations between teat morphology, milk yield and milk fractions. L, teat length; W_1, teat width at the base; α, teat angle; N, teat position; DMP, daily milk production; MM, machine milk; MS, machine stripping milk; HS, hand stripping milk; RM, residual milk.

	L	W_l	*α*	*N*	*DMP*	*MM*	*MS*	*HS*
L								
W_1	0.58[c]							
α	–0.48[c]	–0.39[b]						
N	–0.24	–0.29[a]	0.51[c]					
DMP	0.29[a]	0.36[b]	–0.01	0.18				
MM	0.23	0.24	–0.03	0.14	0.96[c]			
MS	0.17	0.29[a]	0.11	0.28[a]	0.57[c]	0.38[b]		
HS	0.31[a]	0.49[c]	0.03	0.08	0.36[b]	0.10	0.54[c]	
RM	0.21	0.26[a]	0.04	0.12	0.43[c]	0.25[a]	0.52[c]	0.70[c]

[a] $P < 0.05$; [b] $P < 0.01$; [c] $P < 0.001$.

Table V. Effect of three different commercial clusters on machine milk fraction (MM, mL) and on hand stripping fraction (HS, mL) in the milking of ewes according to their teat size (mm). Values are least square means ± SE.

Cluster	*Milk fraction*	*Teat length (mm)* < 35 (22)*	*Teat length (mm)* 35-45 (22)*	*Teat length (mm)* > 45 (21)*	*Teat width (mm)* < 18 (21)*	*Teat width (mm)* 18-20 (23)*	*Teat width (mm)* > 20 (21)*
A	MM	800 ± 35	814 ± 42	1071[b] ± 54	730 ± 39	948 ± 41	928[b] ± 46
B	MM	873 ± 35	852 ± 43	1185[b] ± 54	774 ± 39	999 ± 41	1052[ab] ± 46
C	MM	884 ± 35	890 ± 42	1246[a] ± 54	778 ± 39	1046 ± 41	1102[a] ± 46
Significant difference: *P*<		NS	NS	0.05	NS	NS	0.05
A	HS	140[a] ± 10	198[a] ± 12	274[a] ± 15	128 ± 11	174[a] ± 11	280[a] ± 13
B	HS	116[ab] ± 10	148[b] ± 12	198[b] ± 15	110 ± 11	139[b] ± 11	190[b] ± 13
C	HS	96[b] ± 10	118[b] ± 12	127[c] ± 15	99 ± 11	104[c] ± 11	130[c] ± 13
Significant difference: *P*<		0.05	0.05	0.01	NS	0.01	0.001

* Number of ewes. [a,b,c] Least squares means in columns with different superscripts differ ($P < 0.05$).

Milk composition

The results of milk composition are presented in table VI. The results only differed with respect to the cluster used for the fat, lactose and dry matter contents. These values were similar for clusters B and C, and lower for cluster A.

Kinetic milk emission

Of all the parameters that defined kinetic milk emission, only the time when the milk flow reached its first peak, the maximum flow at the first peak (MF1) and the average flow (Fm) were different depending on the cluster used (table VII). Cluster A had

Table VI. Milk composition (g/L) and somatic cell count (n/mL) obtained from ewes milked with three different commercial clusters in a Latin square experiment.

Milk component	*Cluster*			*Significant difference: P <*
	A	*B*	*C*	
Fat	75.5^{b}	77.2^{a}	77.4^{a}	0.05
Total protein	55.2	55.8	55.7	NS
True protein	51.2	54.9	54.8	NS
Casein	42.1	43.8	45.7	NS
Lactose	48.2^{b}	48.7^{a}	48.9^{a}	0.001
Dry matter	186.7^{b}	190.1^{a}	190.1^{a}	0.001
Ashes	9.9	9.9	10.0	NS
Somatic cell count*	5.13	5.15	5.12	NS

* Log_{10} transformed. [a,b] Least squares means in rows with different superscripts differ ($P < 0.05$).

Table VII. Kinetic milk emission of ewes milked with three different clusters. A + B, liner from A cluster and claw from B; A + C, liner from A cluster and claw from C. 1, first pic; 2, second pic; D, delay of second peak; T, total; V, volume; MF, maximum flow; Fm, mean flow.

Cluster	*Time (s)*				*Volume (mL)*		*Flow (mL/s)*		
	MF1	*D*	*MF2*	*T*	*V1*	*V2*	*MF1*	*MF2*	*Fm*
A	1.1^{b}	27.3	29.2	71.5	366	270	22^{b}	19	8.5^{c}
B	2.8^{a}	28.8	32.5	71.3	412	285	26^{a}	18	9.4^{b}
C	0.2^{b}	25.0	28.4	63.9	415	295	28^{a}	17	10.9^{a}
A + B	0.9^{b}	29.9	32.2	67.8	403	264	28^{a}	17	9.8^{b}
A + C	1.3^{b}	28.8	30.3	71.1	417	276	26^{ac}	17	9.7^{b}
Significant difference: $P <$	0.05	NS	NS	NS	NS	NS	0.001	NS	0.001

[a,b,c] Least squares means in columns with different superscripts differ ($P < 0.05$).

the slowest flow, although the combination of liner A and claws B or C increased both MF1 and Fm.

There were no significant correlations between teat size (L or W) and milk flow.

Teatcup falls

The frequency of teatcup falls is shown in table VIII. Cluster B had the lowest incidence of both active and passive falls, while cluster A gave the greatest number of passive falls.

DISCUSSION

Daily milk production was similar with all the tested clusters because the routine employed included hand stripping, although cluster A had a poorer milk fractioning (lower MM and higher HS) than the others. The HS had a compensatory effect on the total production. The use of clusters B or C would simplify the routine (ie without HS) which could increase milking parlour yield.

Machine stripping yields (MS) were also similar between clusters. This fraction depended on the udder characteristics (Labussière and Ricordeau, 1970). In this experiment they were the same.

A wide and/or flexible liner mouthpiece increases the duration of the communication between both the udder and the teat cisterns and decreases the stripping fractions (Le Du and Bondiguel, 1979; Peris et al, 1989). Lip mouthpiece deflection must have been important in the improvement of milk fractioning of cluster B with respect to cluster A, because B had a narrower bore. The improved results from cluster C as compared with cluster B could be due to its wider bore. Its higher lip mouthpiece deflection might explain its improved results over cluster A. These facts demonstrated that lip mouthpiece deflection was more important than the bore size for milk fractioning. Moreover, the higher volume of the cavity of liner C could have reduced the stripping volume, as O'Shea et al (1983) have demonstrated in cows.

The fact that the difference between clusters was greater with the increase in teat size confirmed the importance of the liner mouthpiece design on milk fractioning, and it also appeared that the length of the teat was more restrictive than its width. The differences in HS were significant between clusters even in the case of the shortest teat (table V). Similar results were observed by Such et al (1989).

Mein (1992), however, indicates that cow teats become longer by 40–50% during milking. In this experiment this would represent an average length of 60 mm after elongation. Given that the length of the liner (9 + 5 in fig 1) was between 102–108 mm,

Table VIII. Teatcup falls in the milking of ewes with different commercial clusters.

Cluster	n	*No falls*		*Passive falls**			*Active falls***			*Total falls*		
		N°	*%*	*N°*	*%*	χ	*N°*	*%*	χ	*N°*	*%*	χ
A	520	500	96.2	14	2.7	a	6	1.1	a	20	3.8	a
B	520	517	99.4	2	0.4	c	1	0.2	b	3	0.6	b
C	520	507	97.5	7	1.4	b	6	1.2	a	13	2.6	a

* Produced by liner slipping. ** Produced by unexpected movements of the ewe. [a,b,c] Different letters in columns differ ($P < 0.05$). χ = chi-square.

what could have happened in the case of largest teats is that the liner did not close completely and thus resulted in a poorer fractioning. A longer barrel might improve this. Mein (1992) also suggests that the bore of the barrel should be 1 to 2 mm narrower than the teat; this was not the case with any of the liners used in this experiment.

The fact that the milk fat content was lower for cluster A was to be expected, because clusters B and C emptied the udder to a greater extent (lower values of RM; table III). It is known (Labussière, 1969; Torres et al, 1985) that milk fractions have a greater fat content when they are located higher up in the udder and thus are last to be milked.

As many cluster design factors were implicated, it is difficult to explain the differences in the time taken to reach the maximum flow of the first peak. The fact that characteristics of the second peak were independent of the cluster used could be related to the alveolar origin of the milk. Milk probably descends from the upper part of the udder little by little and clusters with poor results, such as cluster A, are acceptable. The low flows MF1 and Fm of cluster A could be due to poor milking results and/or to the claw, because after combining liner A and claws from B or C the flow increased. The claws from clusters B and C had an opening and closing vacuum system which was less operative than cluster A (fig 2). This was particularly true in the case of cluster C, which was designed in such a way that the closing of the vacuum was difficult during the change of teatcups. Not closing the vacuum could increase the risk of mastitis in flocks due to brusque removal of the teatcups.

The passive teatcup falls (slipping falls) could be related to cluster design. Passive falls could be caused by very high flow during milking, both a wide bore and/or a deflection of the liner lip mouthpiece or the weight of the cluster. The flow of milk was similar in all the cases so it could not be responsible for the differences in falls. Differences in passive falls were greater in clusters A and C than in cluster B, and were also greater in cluster A than in cluster C. Clusters A and C had the largest mouthpiece bore, the narrowest bore at the end of the liner but a very different lip mouthpiece deflection, suggesting that this factor was less important than the others. The weight of the claw had no effect because, in milking parlours for sheep, it hangs from a band which reduces its effect. Nevertheless, the weight of shell + liner + short milk and pulse tubes had a direct influence on passive falls because they hang from the udder. These weights were 224, 168 and 156 g for clusters A, B and C, respectively, which might justify the greater number of passive falls of cluster A compared with C. In the case of low passive falls it would be possible to reduce the vacuum level in the cluster and with it, the risk of mastitis.

In summary, it seems that the ideal liner was related to the teat size, when the teats were 45 mm long or 20 mm wide, or less, liner type B was optimum, but for longer or wider teats type C was the most optimal.

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