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Original article

Examination of systems that exert traction on the teatcup and reduce teat bending in machine milking of ewes

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Summary — Two systems were designed to exert traction on the teatcups and reduce the bending of teats during machine milking: 1) an articulated arm, which held the teatcups in a fixed position throughout milking; and 2) a system using springs, which were joined to the short milk tube at one end, and hooked onto a wire mesh at the other end after the teatcups were attached. These systems were compared with the traditional milking system in a Latin square design (3 x 3 weeks), using 36 Manchega ewes in their 3rd week of machine milking, after 5 weeks of suckling. Ewes were milked twice a day with machine and hand strippings. The system using springs produced an increase in total milk production compared with the traditionally milked control group, although the increase was not very large (3.7%). However, its composition (percentage of fat and protein) and residual milk did not vary. Fractionation also improved, increasing machine milk by 16% and decreasing the stripping (machine stripping by 60%; hand stripping by 26%). The arm system produced lower total milk production (6%) when compared with that of the control milking system, although the composition and residual milk did not vary. The machine milk fraction was similar to that of the control group, but stripping decreased by 41 and 7% for the machine and hand strippings, respectively. Teatcup falls increased slightly in the spring (6.6%) and arm (8.9%) systems compared to the control milking system (5.1%). The incidence of mastitis, estimated with California mastitis test, did not vary significantly. In conclusion, a simple spring that exerts traction on the teatcup and reduces teat bending gives better milk fractionation. This could be interesting economically when stripping is eliminated from the milking routine (rotary parlours with automatic cluster removers).

machine milking / ewes / stripping / milking efficiency

Résumé — Essais de systèmes qui génèrent la traction sur les gobelets et diminuent la torsion des trayons dans la traite mécanique des brebis. *Nous avons conçu 2 systèmes qui, au cours de la traite mécanique, permettent de générer une traction sur les gobelets et de diminuer la torsion des trayons : i) un bras articulé fixe le gobelet dans une même position pendant toute la durée de la traite, ii) des ressorts, unis aux tubes courts à lait, se fixent à un grillage, au début de la traite. Les 2 systèmes* *ont été comparés au système de traite traditionnel, en un carré latin (3 x 3 sem), utilisant un total de 36 brebis Manchegas qui étaient dans leur 3e semaine de traite mécanique (après 5 sem d'allaitement). Tous les animaux sont traités 2 fois par jour, avec une «routine» comprenant un égouttage machine et une repasse manuelle. Le système de ressort entraîne, par rapport au groupe témoin, une production de lait significativement supérieure (p < 0,001), mais la différence reste peu importante (3,7%) ; en revanche sa composition et le lait résiduel ne varient pas de façon significative. Le fractionnement est aussi amélioré : le lait machine augmente (16%) et les fractions recueillies pendant l'égouttage diminuent (égouttage machine = 60% ; repasse manuelle = 26%). De plus, le taux butyreux augmente significativement dans le lait machine (+0,5 point) et dans les égouttages (+1,9 point), alors que le taux protéique diminue très légèrement (–0,1 point) et de façon significative seulement pour le lait machine. Le système de bras a entraîné, par rapport au groupe témoin, une production totale inférieure (6%), sans modification significative de sa composition et du lait résiduel. Le volume de lait machine et de lait résiduel n'a pas changé mais les fractions recueillies pendant l'égouttage ont diminué significativement (égouttage machine, 41% ; repasse manuelle 7%). En ce qui concerne la composition, seul le taux protéique des égouttages du lait machine a présenté des différences significatives (diminution de 0,1 point). Les chutes des gobelets ont, dans les 2 systèmes décrits, augmenté légèrement par rapport au groupe témoin (témoin = 5,1% ; ressorts : 6,6% ; bras = 8,9%), et le niveau de mammite (CMT) n'a pas varié significativement. On en conclut qu'un système simple de ressorts, générant une traction sur les gobelets et diminuant la torsion des trayons, permet d'améliorer le fractionnement de la traite. Ceci pourrait être intéressant quand les égouttages machine et manuel sont supprimés de la routine de la traite (manèges de traite avec dépose de gobelets automatique).*

traite mécanique / brebis / égouttage / efficacité de la traite

INTRODUCTION

In order to improve milking efficiency, as much milk as possible must be extracted from the udder with minimal manual intervention from the milker. To do this, it is necessary: 1) to improve the descent of alveolar milk to the cistern; and 2) to remove the greatest possible quantity of milk from the cistern and large ducts during machine milking.

The descent of milk from the upper parts of the udder depends on the degree to which the animal is relaxed during milking. This requirement favours the ejection reflex and milk is let down through the network of ducts (Dyusembin, 1978). Any amount of stress could have negative repercussions and lead to a greater retention of alveolar milk. Labussière (1988) has indicated that in ewes with elevated angle of teats from the vertical, machine milking could cause pain because of teat base bending by the cluster weight. Pain could inhibit the ejection mechanism. This hypothesis holds when the average angles of the teats of 1 emission (supplies only the cisternal milk) and 2 emissions (supplies first the cisternal milk and then the alveolar milk) are compared in lacaune ewes. In the first case, the average teat angle was 48.3° while in the second case it was 35.2° (Labussière *et al,* 1981). However, some data cast doubts about the real importance of this fact. For example, although the teats of the Sarda breed are almost horizontal (67.3°), Sarda ewes have a high milk yield and a high percentage of ewes with 2 emissions (Casu *et al,* 1983; Labussière, 1983).

The degree of extraction of the cistern and large ducts milk also depends on udder anatomical characteristics (Sagi and Morag, 1974; Jatsh and Sagi, 1979; Labussière, 1983) as well as on the milking machine factors (Labussière *et al,* 1974; O'Shea *et al,* 1983). One of the main causes of inadequate milk extraction is the congestion and edema of the teat base (Mein, 1992) and the 'crawl' of the teatcups, which can cause strangulation of the teat base by the lip of the liner (Le Du *et al,* 1978; Mein, 1992) particularly at the end of milking. With ewes the teat bending by the cluster weight could also facilitate teat base strangulation (Le Du, 1982). In this way cows tend to be machine stripped, manually or with automated stripping devices (Dethlefsen *et al,* 1990; Hamann and Dodd, 1992), applying extra weight or traction to the teatcup. This pressure results in a partial, but temporary, reopening of the milk passageway to the teat sinus (Mein, 1992). In ewes, machine stripping is a vigorous manual massage to the udder for about 6–10 s, just before the teatcups are removed. This causes more milk to descend through the ducts and also extracts more milk from the cistern. This manual method cannot be automated, though this would be useful in rotary parlours with automatic cluster removers.

The objective of this study is to evaluate the importance of these 2 effects (bending of the teats and traction on the teatcups) in ewes milked by machines modified to avoid these problems.

MATERIALS AND METHODS

Description of the milking systems used

The 3 systems (control, articulated arm, and springs) differ in the position of the teatcups at machine milking. In the control system, teatcups are suspended from the teats in a position tending to vertical because of the weight of the milking unit. A band joined to the claw supports part of the milking unit weight. The weight suffered by the udder was approximately 0.4 kg (interval 0.3–0.5 kg, according to the height of the teats in relation to the height of the claw). In the second system (fig 1), teatcups are joined to an articulated milking arm, which remains in a fixed position, at a constant angle (45° from the vertical) and height (varies depending on the teat) throughout milking. As the teatcup angle was constant, ewes with a teat angle above 45° suffered some teat bending, which was generally lower than the control system. In the third system (fig 2), springs

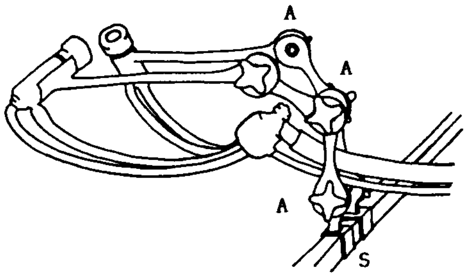

Fig 1. Articulated arm milking system. The articulated (A) and sliding (S) points allow the teatcup to be fixed at any point in space.

are used to pull the teatcups downward during milking, and they also allow the angle of the teatcups to be adapted to the position of the teats. These springs are connected to the short milk tube, where it emerges from the teatcup. The other end is free and is hooked onto the wire mesh after the teatcup has been attached to the teat. The degree of traction exerted by the spring and the angle the teatcup forms are fixed according to the position chosen to hook the spring onto the wire mesh. These 2 systems attempt to reduce any possible pain caused by the bending of the teats and strangulation of the teat base.

Finally, transverse bars were installed in the parlour to separate the ewes and restrict their movement during milking (fig 3). All ewes were milked with these transverse bars in the same parlour.

Experimental design

Thirty-six Manchega ewes were used from the experimental farm of the Polytechnical University of Valencia. Because of the difficulty of using the articulated arm system, ewes who behaved very nervously in the milking parlour were not selected for the experiment. All ewes were in their 3rd week of mechanical milking (after 5 weeks of suckling) and none of them showed any sign of mastitis (negative by California Mastitis Test). They were divided into 3 homogeneous groups taking into account total milk production, milk fractioning (production at the machine milk, machine stripping and hand stripping fractions), and morphologic characteristics of the udder (table I). Each of the

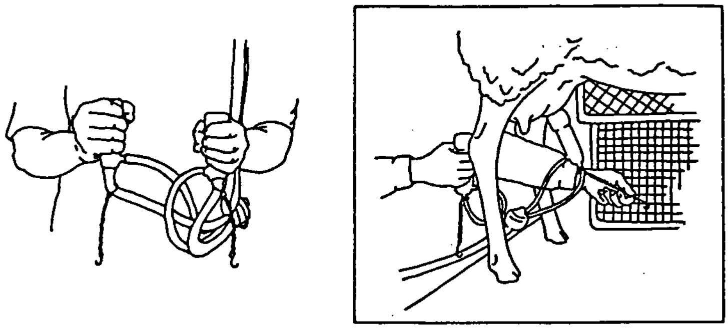

Fig 2. The springs milking system.

groups was assigned 1 of the 3 described milking methods at random, being rotated every 7 d according to a 3 x 3 latin square design.

Equipment and milking method

A high line Casse type milking parlour was used (2 x 12 x 6), with the following parameters: vacuum = 44 kPa, pulsation rate = 120 p/m, pulsation ratio = 50%. The teatcups were made with synthetic rubber liner (Alfalaval, mouth opening diameter 18.5 mm), and were fitted into a metal sheel. The weight of the installed milking unit was approximately 400 g. Ewes were machine milked twice daily at 08.00 and 17.00 h without any udder preparation and using the following routine: machine milking, machine stripping, and hand stripping. Machine stripping was a vigorous udder massage for 5–8 s just before the teatcups were removed.

Data

Data were collected in the last 3 d of each weekly period, the first 4 d enabled the ewes to adapt to the experimental group to which they had been assigned. The amounts of the different milk fractions were measured separately at morning and evening milkings during the last 3 d of each weekly period. The residual milk was only determined for the evening milking on the last day of each experimental period. Composition (fat and protein) was determined separately for fractions of machine milk, strippings (machine plus manual) and residual milk, by means of a near infrared instrument (Infraanalyzer 400D; Techniconn). In the low volume samples (less than 30 cm^3), only fat was analyzed using the Gerber method.

Kinetic emission was determined repeatedly for the morning milking in the last 2 d of each weekly period, following the manual method described by Ricordeau *et al* (1963), but recording the milk flow every 5 s. Ewes were classified with 1 emission (without ejection reflex) or 2 emissions (with ejection reflex) according to Labussière *et al* (1969). The incidence of teatcup falls was recorded with the same frequency as production. In the group milked with the articulated arm, the detachment of the teat from the teatcup was regarded as a fall.

The level of mastitis was determined in the machine milk fraction from morning milking on the last day of each weekly period. The CMT was used for this, giving results in 7 degrees of reaction: 0 (or negative), 0.5, 1, 1.5, 2, 2.5 and 3.

Statistical analysis

The statistical model employed was as follows:

$$Y_{ijklm} = \mu + \alpha_i + \beta_j + \Gamma_k(\beta_j) + \pi_l + \epsilon_{ijkln}$$

where:

Y_{ijklm} = variable studied (production, composition and kinetics of emission);

μ = general mean;

Table I. Udder morphology and milk production of the ewes before the experimental period.

Variable	*Group*						*Significance*
	A (n = *12)*		*B* (n = *12)*		*C* (n = *12)*		
	m	*SE*	*m*	*SE*	*m*	*SE*	
Udder morphology							
Teat angle [a] (°)	45.3	1.8	44.9	1.7	48.1	1.7	NS
Cistern height [b] (mm)	10.1	1.8	10.9	1.9	9.9	1.8	NS
Teat diameter [c] (mm)	15.9	0.4	16.5	0.3	15.4	0.4	NS
Teat length (mm)	35.4	2.2	33.0	1.8	33.8	2.0	NS
Milk production							
Machine milk (ml/d)	850	39	875	47	899	38	NS
Machine strip (ml/d)	119	16	125	13	110	14	NS
Hand stripping (ml/d)	100	14	110	12	96	12	NS
Total milk (ml/d)	1 069	39	1 110	46	1 105	36	NS

[a] From vertical; [b] distance between teat base and lower part of the cistern; [c] diameter of teat, measured at the middle.

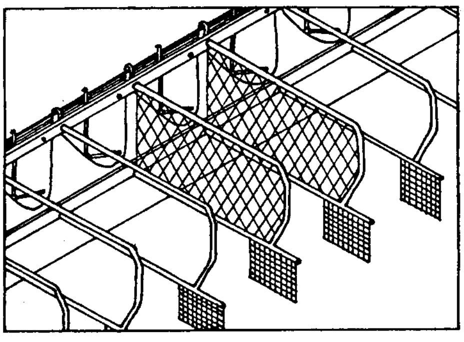

Fig 3. Ewe separators. Ewes were milked with these separators with the 3 milking systems.

α_i = effect of the ewe;

β_j = effect of week;

$\Gamma_k(\beta_j)$ = effect of the day, within the week;

π_l = effect of the milking system;

ϵ_{ijkln} = residual.

For the residual milk variable, the model was the same, but without the day effect. For the statistical analysis the general linear model procedure of the SAS (1988) was used with resulted expressed as least-squares means. The student's *t*-test was utilized to separate least-squares means. Finally, the frequency of CMT variable was analyzed with the chi-squared analysis.

RESULTS AND DISCUSSION

Production and composition of total daily milk

Total milk production was significantly affected by the milking system ($p < 0.001$; table II), the control system gave a production significantly higher (950 ml) than the arm system (895 ml), but lower than the spring system (985 ml). However total milk composition did not vary significantly between the milking systems tested (table III).

The lower total milk production in the arm milking system could be explained by the

Table II. Variation of daily production in various milk fractions by milking system.

Fraction	Milking system			SE	Significance
	Control	Articulated arm *	Springs *		
Machine milk (ml)	755[a]	748[a] (–1)	875[b] (+16)	12	**
Machine stripping (ml)	100[c]	59[b] (–41)	40[a] (–60)	4	**
Hand stripping (ml)	95[c]	88[b] (–7)	70[a] (–26)	3	**
Total stripping (ml)	195[c]	147[b] (–25)	110[a] (–44)	5	**
Total milk (ml)	950[b]	895[a] (–6)	985[c] (+4)	10	**
Residual milk (ml)	83	88	80	8	NS

[a,b,c] Least-square means in rows with different superscripts differ ($P < 0.05$); * the numbers in parentheses are percentage variations with respect to the control values. ** $P < 0.001$.

Table III. Fat and protein content in various milk fractions by milking system.

Fraction	Milking system			SE	Significance
	Control	Articulated arm	Springs		
Machine milk					
Fat (%)	6.04[a]	6.27[ab]	6.48[b]	0.12	**
Protein (%)	5.99[b]	5.87[a]	5.87[a]	0.03	**
Stripping *					
Fat (%)	11.04[a]	11.38[a]	12.95[b]	0.26	***
Protein (%)	5.66	5.59	5.55	0.08	NS
Total milk					
Fat (%)	7.04	7.02	7.05	0.16	NS
Protein (%)	5.96	5.81	5.86	0.07	NS
Residual milk					
Fat (%)	13.19	12.56	13.80	0.41	NS
Protein (%)	4.99	5.19	4.89	0.14	NS

[a,b] Least squares means in rows with different superscripts differ ($P < 0.05$); * strippings = machine stripping + hand stripping; ** $P < 0.05$; *** $P < 0.001$.

possible stress suffered by the ewe as a consequence of the difficulty in positioning the teatcups correctly when attaching the milking unit. In contrast, for the group using the springs system, the connection of the teatcups and springs was very simple, and the higher production could be attributed to the reduction of bending in the teats during milking, and better relaxation and ejection reflex, which would support the theory of Labussière (1988). Nevertheless, it is difficult to accept either hypothesis if one takes into account that no significant differences in the residual milk were found between the 3 experimental groups (table II).

However, although the increase in production in the springs system is significant with respect to the control it is not very large (increase of 35 cm^3, *ie* 3.7%). Bibliographic data show that, if hand stripping is included, the modifications in the milking machine do not produce significant differences in daily production (Sagi *et al,* 1973 ; Le Du *et al,* 1978 ; Sagi, 1978 ; Such, 1990) or these differences, if significant, are not of great importance (< 3%; Le Du, 1981).

Milk fractionation

The milking system affected the 3 fractions significantly ($P < 0.001$) (table II). The spring system proved to be more efficient in draining the udder during mechanical milking and, therefore, left less milk to be extracted in the strippings. Unfortunately, the machine stripping fraction, which requires less effort to obtain, decreases most (60%), and the fraction which is harder to extract, the hand stripping, drops less acutely (26%). The arm system also decreased strippings (machine stripping, 41%; hand stripping, 7%), although the machine milk fraction did not increase from that with the control system. For this reason, the total milk was lower.

The lower strippings of the 2 designed systems could be the result of the traction exerted on the teats by the teatcups. With the arm system, traction is due to the udder retraction throughout milking and, with the spring system, due to the traction exerted by the springs themselves. Moreover, in both cases traction was carried out with little teat bending, except for the arm system, when teat angles varied greatly from 45°. These effects would diminish the strangulation on the teat base at the end of milking and lead to a more thorough extraction of cisternal milk (Le Du *et al,* 1978 ; Le Du, 1982). Importantly, the effect of the springs is not the same as that of increasing the cluster weight. First, the spring increases the traction slightly throughout the milking because of udder retraction (reducing the udder size). Second, when the cluster weight is increased, a bending of the teats always occurs and probably causes more strangulation of the teat base (Le Du, 1982). Thus, the weight of the cluster possibly affects the stripping less in ewes than in cows (Le Du, 1982).

As regards composition (table III), the spring system showed a percentage of fat higher with respect to the control system for both the machine milk (6.48 *vs* 6.04%; $p < 0.05$) and the stripping (12.95 *vs* 11.04%; $p < 0.001$) fractions. The percentage of protein hardly varied, although there was a tendency to diminish with the spring system but differences were only significant for machine milk fraction (5.87 *vs* 5.99; $p < 0.05$). The milk composition at the articulated arm system, also presented a similar tendency to that of the spring system but differences with respect the control system were lower, and only significant for the percentage of protein at the machine milk fraction (5.99 *vs* 5.87; $p < 0.05$). These results would be logical if it is considered that milk coming from the higher regions of the udder tends to possess a higher fat content and slightly lower protein content (Labussière, 1969). It must be pointed out that when finalizing the machine milk fraction, the milk to be removed at the strippings is at 2 levels. Part is in the gland cistern, with composition nearer the machine milk fraction. The rest is in the canalicular and alveolar region, with a composition nearer to residual milk. So when machine milking leaves less milk at the gland cistern, the composition of strippings will be nearer to the residual milk. This process could explain the spring system results but not the arm system results, because the arm system produced a machine milk fraction similar to the control (table II).

Kinetic emission

The classification of ewes with respect to the number of emissions (*ie* 1 or 2), showed no differences when udders were subjected to the 3 milking systems tested. However, some kinetic parameters were affected (table IV). With the 1 emission ewes, the milk flow-rate was significantly affected by the milking system; the arm system produced maximum and average flows that were lower than those in the other 2 groups. On the contrary, with the 2-emission ewes, the flow did not vary significantly among the 3 groups. This could be explained because 1-emission ewes are less adapted to machine milking, since they do not present the ejection reflex (Labussière *et al*, 1969). Thus, they would possibly suffer more stress during the teatcup attachment of the arm system. Stress would have affected the tone of the teat smooth muscle and, therefore, the milk flow-rate (Bruckmaier *et al*, 1992; Butler *et al*, 1992; Mein, 1992).

The milking time was significantly affected by the milking system, both in 1- and 2-emission ewes. The spring system gave 8–9 s more machine milking time than the control. This extra time was probably when the machine stripped the udder more and obtained a higher machine milk fraction. The arm system also tended to increase the milking time compared with that of the control, but the differences were only significant in 1-emission ewes.

Teatcup falls

The number of teatcup falls was highest using the milking arm system (8.9%), fol-

Table IV. Parameters of the milk emission kinetics, by milking system.

Parameters	*Milking system*			*SE*	*Significance*
	Control	*Articulated arm*	*Springs*		
One-emission ewes [1]					
F_{max} (ml/s)	14.6^{b}	12.3^{a}	15.0^{b}	0.9	*
F_{mean} (ml/s)	6.4^{b}	4.6^{a}	6.0^{b}	0.3	***
T (s)	54^{a}	63^{b}	62^{b}	3	*
Two-emission ewes [2]					
First emission					
F_{max} (ml/s)	15.3	13.7	15.4	0.6	NS
F_{mean} (ml/s)	10.5	10.2	11.2	0.4	NS
T (s)	27	26	26	1	NS
Second emission					
F_{max} (ml/s)	13.4	13.4	14.1	0.6	NS
F_{mean} (ml/s)	4.9	5.0	5.1	0.2	NS
T (s)	45^{a}	50^{ab}	55^{b}	2	**
Globally					
F_{mean} (ml/s)	6.9	6.7	7.1	0.2	NS
Total T (s)	72^{a}	76^{ab}	81^{b}	2	**

[a,b] Least squares means in a column with different superscripts differ ($P < 0.05$). [1] $n = 16$; [2] $n = 20$. F_{max} = maximum flow-rate measured in 5-s periods, F_{mean} = mean flow-rate, T = milking time. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

lowed by the springs system (6.6%), and finally the control group (5.1%). Falls in the arm and spring systems were increased for several reasons. First it was difficult to fix the spatial positioning of the arm and the traction level of the springs to be as compatible as possible to drain the udder better and not increase falls (effect of the reduction in udder size during the milking). Second, there were movements made by the ewe during milking (variation in the spatial position of the udder). Nevertheless, the separators limited movement sufficiently in the spring system (see fig 3) but not in the arm milking system. Third, these systems cause a higher number of falls throught 'kicks'.

The fact that the teatcup falls were not greatly different among the 3 groups, could probably be explained because animals who were not very nervous were chosen for the experiment. In addition, the experiment took place 3 weeks after machine milking had begun, giving ewes time to become accustomed to the milking machine. Moreover, the experimental milking systems probably tend to diminish the 'passive' falls associated with the elevated angle of the teats (Casu *et al,* 1983; Labussière, 1988); it is expected that these particularly falls would be more frequent in the control milking system.

Mastitis

The level of mastitis, estimated using CMT, did not show significant differences among the 3 groups studied (table V). However, given that the period of milking for each group lasted only 7 d, the possibility of adverse effects with regard to mastitis over a longer period is unknown. More extensive studies are required to determine whether these systems affect the teat condition (Hamann, 1987) or the frequency of liner slips and the impact mechanism (O'Shea *et al,* 1983; Bramley, 1992).

Table V. Number of cases in each level of California mastitis test by milking system.

Milking system	*Level*			
	0	*0.5*	*1*	*>1*
Control	30	4	0	1
Articulated	33	2	0	0
Springs	31	3	1	1

CONCLUSIONS

The effect of avoid bending of teats at the spring system could have been responsible for the increase of 3.7% in total milk production. Although this would indicate a better ejection reflex, the results (no differences in residual milk and classification of ewes with one or two emissions) do not support this hypothesis. Nevertheless, these results are restricted to the conditions of this experiment: ewes at third week of machine milk and with an average teat angle of about 44–48°.

A simple spring, exerting traction on the teatcup and reducing teat bending, improves fractioning, increasing machine milk (16%) and decreasing stripping (machine stripping, 60%; hand stripping, 26%). Nevertheless, there are some drawbacks: additional time needed for attachment of the springs (5–6 s), and a probable increase in teatcup falls. Therefore, this method could be only of economic interest if there were a better response to the hand stripping omission, given the decrease in this fraction (26%), or in routines without any stripping (rotary parlours with automatic cluster removers), given the increase of the machine milk fraction (16%).

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