Introduction

There are a number of methods to improve the quality and quantity of milk, some of which have been neglected in the past 20 years. Indeed, much work has been dedicated to feeding and genetic improvement of milk yield and composition, but milk retrieval at milking has been considered as secondary because milking equipment technology has not considerably evolved. But now the gains to be expected from feeding are reduced, investment returns are increasingly uncertain, and work is more complex. In Europe, the extension of milk quotas (restriction of the right to produce) to small ruminants have encouraged farmers to seek technical solutions to improve the quality of the milk and at the same time simplify working procedures. Some of the answers to their plea lie in a better understanding and exploitation of the milk ejection mechanisms.

Review of Milk Synthesis and Ejection

After a phase of mammary growth (secretory alveoli and ducts) mainly controlled by ovarian steroids, the milk surge, or lactogenesis, will necessitate stimulation of secretory cells by a number of pituitary hormones; prolactin and ACTH in particular. Note that inducing lactation artificially only requires steroid administration to prepare the udder for these pituitary hormones before turning the animals to milking. Milking, through udder stimulation, induces the release of a hormone compound necessary for the ultimate phase of mammogenesis and the induction of lactation. Once lactation has been induced, its maintenance will require, in addition to the above hormones, other hormones that preferentially act on mammary metabolism, such as growth hormone (GH). There again, it is worth noting that udder clearance is always followed by GH release. This also explains the so-called lactation maintenance reflex linked to mammary gland stimulation. Once the milk has been produced, it still has to be drawn from the udder, otherwise drying-out will occur very quickly. This means that the accumulation of milk, adding to the lack of the hormones required for milk synthesis, will stop the cellular mechanism. Two reasons have been put forward. First, pressure in the secretory alveoli crushes alveolar cells and impedes secretion vesicle transfer and also slows down the passive passage of elements from blood to milk. The second cause is thought to involve one or several lactoserum peptides (Feed Back Inhibitor of Lactation : FIL) which, by accumulating in the alveoli, would have an inhibitory effect on lactose synthesis. This clearly demonstrates the importance of thoroughly draining all the milk contained in the alveoli at each milking. But thorough draining requires the active participation of the animal. Indeed, if between milkings the milk is partially discharged into the cisterns in the lower part of the udder, some of it remains in the alveoli and in the small galactophores at the top of the udder. That milk contains much more fat because fat cells are larger than the diameter of these small ducts. To be extracted, that milk must be expelled from the alveoli by the pressure applied on the alveolar wall by myoepithelial muscle cells. These
cells spontaneously contract (smooth muscle cells), but the ejection of milk will only be effective if their contractions are synchronized, which can only be achieved if they are stimulated by a neuro-pituitary hormone, oxytocin. There again, the release of that hormone in blood results from a neuro-humoral reflex initiated in the udder. So optimizing milk ejection comes down to retrieving the milk and usable matter that was produced through genetic selection and feeding and thus optimizing the animals’ potential. The milk, by going down into the cisterns, increases the intramammary pressure and the pressure ratio between the cisterns and the mouth of the sucking lamb or the machine vacuum nozzle. This also accelerates draining and makes milking quicker.

Lastly, if all information transits through the central nervous system, it is likely that the CNS may act as a modulator of response to udder stimulation. For instance, the connections of the oxytocin-producing hypothalamic nuclei (supra-aortic and paraventricular nuclei) to the limbic system, which is the emotion site, and the cortical areas which are the memory sites, explain why recognition of an anxiety factor (biting dog, stranger in the farm, sudden replacement shepherd, bleating of lambs, undergoing such treatments as injection or foot trimming, shearing noise) may inhibit oxytocin release and hence milk ejection. Other factors, on the contrary, may facilitate milk ejection. In suckling farms, it is the sight and cry of the young and in dairy farming, when all is well, the sight of the usual milker, the starting of the vacuum pump and/or pulsation, entering the milking pen and above all concentrate feeding in the milking pen. It has to be noted that there is a close relationship between oxytocin and another peptide: CCK (cholecystokinin). Although this has not been proven in ruminants, the CCK released at the peripheral level when the feed bolus reaches the stomach is thought to induce oxytocin release and might therefore promote milk ejection. However, CCK may also be released at the central level, which controls rumination. But oxytocin may in turn induce CCK release. This implies therefore that rumination nearly always follows oxytocin release and milk ejection. An animal that does not ruminate in the milking pen is therefore under unfavorable conditions and surely does not express its full potential.

So respecting the animal, stimulating it as much as possible may appear coarse (but not that easy) but is necessary to extract all the secreted milk as quickly as possible and to maintain lactation.

**Milk Ejection**

Milk ejection, which in dairy cows usually occurs during massage and in the first minutes of milking, has to take place within only two milking minutes in ewes. It therefore requires careful animal selection and optimal setting of the milking machine. Milk ejection can be monitored during milking without using any invasive technique and without bothering the animals. Measuring the milk emission output at milking is sufficient. The technique has produced very interesting results in terms of the distribution of milk in the udder and is still a reference method for selecting animals according to their milking easiness. In ewes, milk generally flows in several stages. The first outflow peak corresponds to cisternal milk discharge. Then a second outflow peak occurs only if the nervous connection between the udder and the CNS is unimpaired. That outflow therefore depends on oxytocin and represents the volume of milk trapped in the small galactophores and the alveoli. That milk is called the alveolar milk. Lastly, a third increase in outflow is noted at the time of stripping. That milk fraction represents the milk kept below the teat in the mammary gland pockets. But if the ejection of alveolar milk is incomplete, the massage performed during stripping and the tap stimuli applied by the milker under the udder will help in retrieving all or part of the alveolar milk with that fraction. Note that in the early days of mechanization, the poor performance of the machines, and the large number of ewes that did not respond to mechanical milking stimulation forced the milkers to perform hand milking to retrieve residual milk after removing the milking
bundle. That operation is now rarely performed.

In 1982, almost half of French Lacaune ewes were unresponsive and necessitated time-wasting and tedious stripping and manual re-milking operations for all the milk produced to be retrieved and collected. In 1995, only 7 to 8% of these remained and essentially among ewe-lambs. Those ewes which only emit their cisternal milk have lower milk yield, less rich milk (up to 70% of the fat can be trapped in the alveolar fraction between milkings) and poor lactation persistence. These ewes therefore are removed from the flocks. It should be noted also that ewes with poor reflex have a lower milk outflow, inducing protracted milking times. It is therefore important to carry on selecting ewes according to their milk emission kinetics. Nowadays, because of the sharp increase in the volume of milk produced, it is frequent that the cisternal milk has not finished flowing when the alveolar milk ejected by the action of oxytocin reaches the teat. As in cows and goats, it becomes difficult or impossible to distinguish between the two emissions and to measure their respective outflow. At the most, the reflex is known to have occurred if the milk emission kinetics lasts for more than 40 sec. with a high outflow, which is the maximum time for effective oxytocin release. There is a good correlation between the cisternal milk volume and milk yield. That volume currently represents as much as 38% of total milk yield on average. The alveolar milk volume is similar (34%) and so up to 28% of total milk is represented by stripping milk. Stripping is therefore mandatory. But a large part of that stripping milk is linked to the mammary gland morphology, not to a problem of effective milk ejection. Selection according to milk production performance has resulted in larger cistern volumes, partly due to the enlargement of the pockets at the base of the udder. Consequently, the teats are higher and their position precludes complete drainage of the mammary gland. Furthermore, that teat position makes the fitting of nozzles more difficult and may induce air intake or bundle disconnection detrimental to the udder health (impact on teats and increased risk of germ contamination). It is therefore crucial, as in dairy cows, to select ewes in consideration of their udder morphology and by choosing animals with teats as vertical as possible, properly draining the udder. Combined with a good oxytocin release, vertical teat placement will warrant effective milking, which can be simplified by automatic disconnecters, a technique known to reduce overmilking and improve teat health in cows. Among the various ewe breeds, some have milk emission kinetics with a single outflow peak, high volume emission (a characteristic of Friesian ewes). If there are fewer of these ewes with oxytocin release at milking than the more highly selected Lacaune ewes, it is nonetheless true that these animals offer large cistern volume and the ability to transfer alveolar milk into cisterns between milkings. This ensures that synthesis will not be hindered and that the secretory potential will not be reduced throughout lactation. In addition, poor setting of the milking machine or the presence of milking-refractory animals will have less impact and milking will be simplified.

The effect of oxytocin release between milkings on the distribution of milk in the udder and on milk yield has been verified. It appeared that if blood oxytocin is maintained throughout the day at the same level as during milking, the storage volume increases in proportion with total milk and the alveolar milk volume slightly decreases and holds. The result is a 18 to 25% increase in milk yield. Whatever the reason, good milk transfer between milkings thus appears to be as important a factor of better milk yield and easier milking as milk ejection during milking. It is worth noting that luteal oxytocin could be among the factors causing that transfer, because milk transfer in the cisterns increases when there is sexual activity. Other milk ejection factors have been evidenced in ovaries, which led us to deepen our knowledge of the relationship that exists between the ovarian sphere and the udder.

Oxytocin titration is not informative on the occurrence of milk ejection because the important
factor is the form of release rather than the amount of oxytocin released. Indeed, sustained oxytocin release results in high intermammary pressure during milking and thus quicker and complete draining of the udder. There is also a very small number of cases when oxytocin release occurs and has no effect on the udder. There are multiple reasons for that but the most likely ones are the absence or deactivation of receptors on the mammary gland. Catecholamine release may also occur at the peripheral level, reducing mammary blood flow to a point where the oxytocin level is no longer sufficient to ensure effective alveolar contraction. Considering the costs of oxytocin assays and the necessity to perform several of these tests in the course of one milking, the method should remain experimental or at the most be used to select the best breeding ewes in breeding units.

Ewe Management at Milking

There are a large number of different ways to manage dairy ewes. In the very intensive Mediterranean systems, ewes are managed in the same manner as dairy cows and weaning occurs immediately after lambing, followed by exclusive milking to the end of lactation (150 to 200 days). In that case, the lambs are artificially reared and are difficult to train because they never learn from their mothers. In many cases, however, a variable suckling period precedes exclusive milking. In the most extensive flocks, lambs are suckled to weaning. In intermediate cases, the point is to provide colostrum cover and to await the seasonal opening of specialized creameries such as those of the Roquefort region in France. In that case, however, the milk production in Lacaune ewes, which has doubled in 20 years and largely exceeds the intake capacity of the lambs in the early stages of growth, no longer permits exclusive lamb suckling without hindering lactation. For that reason and, according to some authors, milking has been combined with suckling for complete mammary gland drainage and to train the ewes to come to the milking pen. How to choose between those systems? According to Labussiere’s results, it appears that the more the ewes suckle their lambs, the greater difficulty they have to give their milk to the machine while releasing oxytocin. The drop in milk yield observed at weaning (23 to 35% according to breed) and explained mostly by the reduced frequency of daily drainage (-20 to -25%) but also by the mother-lamb separation effect (estimated at -3 to -7%) inhibiting the ewes’ adaptation to mechanical milking. Mixed management never really reduced the drop in milk yield at weaning. This is clearly explained because our recent studies have shown that as long as the ewe has daily contact with her lamb, she refuses to release oxytocin at milking, whereas she does it without any problem when suckled (selectiveness). The proximity of the lamb in the milking pen (unfeasible in practice) restores the milk ejection reflex, which demonstrates the necessity of the lamb effect (most probably olfactory and visual) for milk ejection to occur. Ewes however get used to the milking pen and passing to exclusive milking is made easier by their calmness. As early as 48 h after lamb separation, the ewes begin releasing oxytocin at milking, contrary to exclusively suckling ewes, a proportion of which will never adapt. The rate of adaptation to milking is also the same as that observed in ewes turned to exclusive milking upon lambing. This latter method however has to be considered with caution. Our studies show that oxytocin release is less effective if the mother does not establish her maternal instinct, i.e., if the first sucklings are not performed. So a 24-h maximum contact between ewe and lamb is beneficial, and the lambs remain easy enough to train for artificial suckling. Although this remains to be verified experimentally, our results and those of “controle laitier” would tend to show milk yield to be higher as mixed management lasts longer. These results could be easily explained by the establishment and repeated stimulation of a strong ejection and secretion reflex, effective in early lactation, which would potentiate the ability of the cellular mechanism to synthesize milk to the end of lactation. Lastly, mixed management permits functional selection based on the morphology of the udder and teats because as a rule the ewes not capable of suckling their lambs are removed from the flock. Consequently, flock
homogeneity is greater and milking is easier. Although no reliable data are available in that respect, the users of the various methods have not reported any significant effect on udder pathology.

**Milking Machine**

The milking machine must be stimulating enough to ensure strong milk ejection during the very short milking time. Also, ewe milking includes time-consuming manual operations (stripping and possibly “re-milking”) that should be reduced to a minimum, in particular by selecting well-formed udders.

Proper setting of the machine however may help increase the productivity of the milker and at the same time simplify his task. Initially, choosing a pulsation rate as high as 180 ppm was motivated by the need to emulate the natural conditions of lamb suckling as best as possible. All our experiments aimed at comparing pulsation rates from 60 to 180 ppm have shown that milk yield is very slightly higher when the rate is set above 120 ppm. The mechanical milking and stripping milk volumes do not vary significantly, but the most spectacular effect is an increase in the re-milking volume at 60 ppm, whether the pulsation ratio is 33 or 50%. Pulsation ratio trials tend to show that ratios below 50% would incompletely drain the teats. Oxytocin assays elicited significantly lower release in that case, and it can thus be concluded that a pulsation rate below 120 ppm is too low to stimulate Lacaune ewes and does not ensure total drainage and retrieval of all the usable matter. It should be noted also that cup drop is more frequent (with rubber liners) when the pulsation rate is low.

The vacuum pressure chosen is between 36 and 53 kPa. The most recent tests we performed showed that the vacuum effect is mainly sensitive on the percentage of milk retrieved after stripping. This may be due to a disruption of mammary drainage induced by teat elongation, liner clambering and very obvious congestion of the teats. This effect therefore is more a physical one. However, considering that the vacuum pressure setting is a trade-off dictated by the weight of the bundle and the need to prevent it from failing off, the solution could be to operate under lower vacuum pressure (36 kPa) with lighter bundles and better gripping liners (silicone). However, with no air intake at the clamp, the rated vacuum pressure under the teat may transiently exceed the regulator pressure and damage the teat while increasing the leukocyte count. It is therefore recommended to maintain some air intake, even if it means increasing the vacuum reserve slightly. The best trade-off would therefore imply low vacuum pressure (36 kPa) and high pulsation rate (180 ppm) with a 50% ratio. Note that with such a setting the leukocyte count will be higher than with a lower pulsation rate. There is no upper aggression on the mammary tissue. In fact that effect is only sensitive in animals with leukocyte counts above 200,000 cells per milliliter (sterile controlled milk). So the increase in leukocyte count is only the result of the expulsion of the cells contained in the alveoli, through which they enter the udder. This clearly confirms better drainage induced by oxytocin and permits earlier detection of possible udder infections. Lastly, the choice of liner is crucial for optimal application of the machine settings to the teat. There is no impact on milk yield if the milker performs proper stripping. This means that the teat liner has to be chosen carefully to facilitate physical drainage of the udder. Silicone liners appear to reduce cup drops and liner slipping and are therefore recommended. However, the most spectacular effects are produced by the design of the cup and the flexibility of the liner body. Stripping is highly reduced when the cup diameter is increased to restrict teat squeezing at the end of milking. Otherwise air intake is facilitated and cup falls are more frequent. A very hard liner may increase stripping considerably because it moves more slowly and remains open longer than a softer liner. Indeed milk outflow can be accelerated but the effect of that on the teat is deleterious (upper congestion) and the liner clambering is more marked. The flaring
A number of factors are yet to be tested or re-tested because of the ongoing standardization of milking equipment for small ruminants. Further advances are still possible through blood oxytocin assays, measurements of teat congestion and udder immunological condition assessment, as indices of the physiological effect of the equipment and of udder health.

Conclusion

Adding the losses in milk and usable matter to those in milker time and discomfort that can be endured unknowingly when operating under poor conditions, the losses can add up to impressive figures (up to 20-25%). It is therefore necessary to use animals with good mammary conformation (large cisterns, well drained by vertical teats at their base), good sensitivity to stimulation by the milking machine, and good and sustained oxytocin release during and possibly between milkings. High milk output at milking will ensue and the working time will be reduced accordingly. In more intensive systems, ewes exhibiting low maternal instinct will be preferred to facilitate weaning and adaptation to mechanical milking. The equipment will be adjusted so as to be stimulating (high pulsation rate) and optimize oxytocin release and increase drainage effectiveness and unaggressive (low vacuum pressure) to avoid tissue congestion and poor teat drainage, which would necessitate additional manual operations. All these operations, by better draining the udder, will ensure and maintain better milk yield throughout lactation, all the more so as they are performed frequently in early lactation. In that respect, mixed management appears to be an additional asset if the right to produce is not restricted.

Main References

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