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Review: Milking routines and cluster detachment levels in small ruminants

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Small ruminants not only differ on mammary gland anatomy, milk's properties and the amount of milk yielded comparable to those of dairy cattle, but also on the milking routine strategies and machine milking settings to maximize daily milk secretion. The udder compartment is proportionally larger in dairy sheep and goats, which requires modifications in the milking machine settings, milking procedures and allows the use of different milking strategies as they better tolerate extension of milking intervals. Depending on the breed, cisternal milk in goats varies from 70% to 90%, whereas in dairy sheep it varies from 50% to 78% of the total gland capacity. This explains why these species are commonly milked without pre-milking teat preparation, while in goats it is applied only in cases of high prevalence of intramammary infection in the herd. Recent French researchers observed that 40% of the goats presented an unbalanced udder as well as unbalanced morphology (21% to 30%) and functional milk flow (around 10% to 20% more) which could induce overmilking. In dairy sheep, selection for higher milk production increases teat angle insertion. Thus, to increase machine milk fraction, it is recommended to use either the 'Sagi hook' as an alternative for lifting up the 'pendulous' udder during milking or to perform machine stripping. There are three cluster removal strategies for small ruminants: manual, timed and milk flow driven automatic cluster removal (ACR). Automatic cluster removal reduces overmilking, improves teat condition, enables labour saving and provides a consistent milking routine in small ruminants. There are three to five main milk flow profiles in ewes and goats, which result in curves with one or two peaks (or plateau) and different patterns of the milk flow decreasing phase due to the degree of mammary gland imbalance and teat characteristics. When taking into account our current knowledge, ACR recommended take-off settings for goats are: 200 g/min + 10 s delay time (DT) for a long decreasing phase or two plateau curves and 500 g/min + 5 s DT for a short decreasing phase and one plateau curve. The ACR take-off settings for ewes are: 150 g/min +10 s DT for long decreasing phase and 200 g /min + 5 s DT for a short decreasing phase. This review is intended to be useful for scientists and producers seeking basic knowledge of milking routines and cluster detachment settings for parlour performance and milk quality.

Keywords: milking routines, automatic cluster removal, milk flow, sheep, goat

Implications

This review article focuses on milking routines and cluster detachment levels proposed for dairy sheep and goats. The proposed milking routines with cluster detachment levels ensure a quick and gentle milking process. The information presented will be useful for scientists and producers seeking basic knowledge of milking routines and cluster detachment settings for parlour performance and milk quality.

Introduction

The milking process in small ruminants differs from that observed in dairy cows. The guiding objective for successful milking and efficient production is to obtain maximum milk yield in the shortest time. Milking routines in small ruminants mainly depend on the anatomical and physiological characteristics of the animal, milking management and the level of automation of the milking parlour. These routines were constant during the last decades, but they have started to slowly change due to the increase in the number of animals and milk production, udder morphology, and with more prevalent automation of the farms. The oldest complex milking routines included double cluster attachment, intense pre-stimulation (scarce), machine milking, and machine stripping followed by hand stripping called 'repasse' (Ricordeau *et al.*, 1963; Bueso-Rodenas *et al.*, 2015). Thereafter, the milking routine was simplified to including teat-cup attachment, machine milking, machine stripping

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and manual teat-cup removal. Current milking routines for sheep and goats follow the recommendations established for dairy cows but omit teat preparation, and machine stripping and includes automatic cluster removal (ACR). However, the impact of ACR equipment in these species has not been evaluated. The internal structure of the small ruminant udder includes two independent mammary glands under the skin bag, with each gland wrapped in its own bag of elastic connective tissue. Each gland consists of a large cistern divided into the glandular cistern and teat cistern. The udder also contains of the alveoli or branched mammary ducts. Milk is stored in either the alveolar tissue or the cisterns. As reported by several research groups, large differences between species and breeds exist with regard to the proportion of total milk that can be stored within the cisternal compartment. This demonstrates that selection for milk yield resulted in larger cisternal udders to accommodate the greater milk volumes (Rovai *et al*., 2008). Because of this selection, pre-stimulation may not be necessary to obtain optimal milking characteristics during machine milking of sheep and goats. This is most likely due to large amounts of cisternal milk, which allows milk ejection to be induced along with the start of milking. Researchers described that pre-stimulation along with an opportune release of oxytocin (OT) during milking does not significantly influence the course of milk flow in Swiss Saanen goats, where no bimodality was observed with or without pre-stimulation (Bruckmaier *et al*., 1994). In contrast, milk yield per milking was increased with pre-stimulation during late lactation. Furthermore, strip yield was lowest in early (0.1 kg) compared to mid and late lactation (0.15 kg). It was also observed that OT release within 30 s after the start of milking was not affected by pre-stimulation (Bruckmaier *et al*., 1994). However, sometimes a subsequent release was detected during hand stripping. In the 70s and 80s, specific breeds of dairy ewes were not well adapted to milking, and thus did not display milk ejection during milking without pre-stimulation (Labussiere, 1988) warranted conditioned the later omission of this management practice in the 90s for more selected breeds. The Lacaune dairy breed exhibited a significant concentration of OT release within 30 s of teat-cup attachment in 92.5% of animals. Regarding the end of milking stripping, researchers revealed the possibility for omitting the procedure and allowing for end of milking automation strategies. Recent research in Murciano-Granadina goats showed that 2 min of overmilking caused significant increase in teat wall thickness, teat wall area, teat end area and teat canal length (Alejandro *et al*., 2014). It was also discovered that an increase in the teat wall area and thickness in Manchega ewes occurred after 2 min of overmilking. Another experiment described that overmilking in dairy sheep (1.5 to 2 min) and an increase vacuum level from 36 to 42 kPa caused increased teat thickness but not necessarily a difference in new intramammary infections (IMI) or increased somatic cell count (SCC) during 10 weeks of lactation (Peris *et al*., 2003). Nevertheless, the practice of overmilking during the whole lactation, along with the increase of the teat thickness, may contribute to the development of new IMI, especially during summer months. The influence of overmilking on the teat tissue is more pronounced in goats than in sheep. The reasoning behind this is that goats experience a longer machine milking duration and increased frequency of unbalanced udder emptying. Consequently, there is more exposure to liner compression and vacuum load on the teat. Therefore, these results favour the notion of simplifying and automating the end of milking procedures, as there has been a recent increase in ACR utilization which increases small ruminant farm efficiency (Bueso-Rodenas *et al*., 2014). The aim of this article is to review present milking routines and cluster removal strategies in small ruminants based on different milk flow profiles associated with different anatomical and physiological conditions. This article will be divided into the following chapters: udder morphology and milk ejection, milking routines, milking machine system and milking routines and milking frequency and ACR.

Udder morphology and milk ejection

Milk yield in dairy sheep is positively correlated (0.4 to 0.71) with udder and teat traits in Manchega and Tsigaya dairy sheep, respectively (Labussiere, 1988). Moreover, increased milk yield was found to be associated with udder width and udder height as well as with udder circumference (Fernandez *et al*., 1995). A recent study reported that milk yield was positively correlated to udder circumference, udder depth and width, and distance between teats either during suckling or machine milking periods in Najdi ewes (Ayadi *et al*., 2014). Domestic breeds display better udder morphology for machine milking (shorter teat angle and smaller cistern height) compared to dairy ewes that have been rigorously selected for improved milk production, such as Awassi and East-Friesian (Sagi and Morag, 1974; Dzidic *et al*., 2004), and Lacaune (Marie-Etancelin *et al*., 2006). Moreover, Rovai *et al*. (2008) and Ayadi *et al*. (2014) have also observed that teat angle is positively correlated with the distance between teats. This indicates that large udders have more horizontally placed teats which makes the ewes milk out slower, harder and not completely. The heritability of udder quality traits varies, with high values for udder shape and teat placement in the Churra dairy breed (Fernandez *et al*., 1997). Furthermore, the genetic correlation between udder shape and teat placement was also high at 0.96. Milk and protein yield were highly correlated with udder depth (0.82 and 0.83, respectively), whereas teat placement was negatively correlated with the same traits (−0.34 and −0.40, respectively). These results indicate that selection schemes for higher udder depth would increase the yield of both milk and protein. On the contrary, increased milk yield and protein yield result in worse teat placement. As a consequence, the incidence of teat-cups falling off during the milking process and/or air leakage during machine milking stripping would increase. These findings reveal the importance of incorporating udder morphology measurements in the breeding programmes of

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ewes. It was previously observed that teat angle and cistern height are increased along with parities in Churra dairy ewes (Fernandez *et al*., 1995). The same research study showed that at least two out of three flocks presented significant differences for udder and teat measurements. Udder width, height and circumference have highly significant positive effects on milk yield in Churra ewes. Variables (cistern height and teat position, angle, length and width) that determine morphological aptitude to machine milking displayed measures of high repeatability. Lacaune ewes had greater udder depth and cistern height compared to Manchega ewes that had larger and wider teats. There is no doubt that dairy sheep increase udder capacity by vertical enlargement, which increases milk yield. Along with the negative impact of higher teat angle, thicker teats decrease milk flow rate and increase stripping milk fraction (Sinapis *et al*., 2006). These data are confirmed by previous internal evaluations of cisternal capacities.

Cisternal and alveolar milk partitioning

Ewes can be classified due to their cistern size: large (Lacaune and Sarda 74% to 82%), medium (East-Friesian crossbreed, Manchega, Sicilo-Sarde and Najdi 55% to 67%) and small (non-selected or non-dairy ewes or meat ewes). The functional evaluation of milk partitioning between udder compartments has previously been utilized by several authors to evaluate cisternal capacities. Milk within the udder is stored in two compartments: alveolar (secreted milk stored within the lumen of alveolar tissue and small ducts) and cisternal (milk drained from the alveoli and stored within the large ducts and the gland and teat cisterns). Cisternal milk can be harvested by using a teat cannula after application of an OT blocking agent, while alveolar milk is collected after an OT injection. Differences in size between compartments vary between species, breeds, milking intervals and stage of lactation (Salama *et al*., 2004). The cisternal milk fraction in dairy ewes varies between 50% and 78% (Rovai *et al*., 2008). Cisternal and alveolar milk fraction are positively correlated (0.94 and 0.85, respectively) with total milk yield in Najdi ewes (Ayadi *et al*., 2014). Alveolar milk and cisternal milk quantity were also highly correlated (0.86 and 0.99, respectively) with total milk yield in Majorera, Tinerfena and Palmera dairy goats (Suarez-Trujillo *et al*., 2013). Interestingly, the same study did not discover differences in the number of alveoli between goats subjected to once and twice daily milking. This suggests that the strategy utilized by goats to adapt milk secretion to udder capacity is to reduce the synthetic and secretory activity instead of modulating alveolar number or the number of cells per alveolus via apoptosis induction (Ben Chedly *et al*., 2011). In Tinerfena dairy goats it was shown that milk yield and milking ability parameters were more related to the globulousness of the udder than udder length measures (Capote *et al*., 2006). In Sarda dairy ewes, there is a stronger positive correlation between cisternal milk fraction (0.97) and total milk yield than between alveolar milk fraction (0.63) and total milk yield (Nudda *et al*., 2000). Moreover, despite the differences in daily milk yield, alveolar milk did not vary when comparing the Manchega and Lacaune breeds as reported previously (Rovai *et al*., 2008). These data emphasize the importance of the cisternal compartment rather than the alveolar compartment for maximizing daily milk secretion in dairy sheep. The number of alveoli and mammary epithelial cells usually decreases in Sarda dairy ewes during lactation, with the highest values observed 10 days before parturition. This decrease explains the decrease in milk yield reduction (Castanares *et al*., 2013). Mammary gland volume, which was highly correlated with mammary gland weight, explained 62% of the milk yield variability during lactation.

Milk flow kinetics

Measuring milk flow over the course of milking is one of the most common techniques applied to evaluate udder emptying in goats and ewes. Classification of goat milk flow kinetics began with studies that presented two types of milk flow curves which were explained by either one peak or plateau phase (Bruckmaier *et al*., 1994). More recent studies have described five main milk flow types (Legris *et al*., 2016). Milk flow with one or two peaks has previously been observed in Préalpes dairy ewes (Labussiere *et al*., 1969). A third curve was later observed in Ostfriesian and Istrian dairy crossbreed ewes with a low flow plateau and without administration of OT (Bruckmaier *et al*., 1997; Dzidic *et al*., 2004). Bimodality in dairy ewes has displayed a clear separation in peaks, whereby the first peak represents the cisternal milk fraction and the second peak represents the alveolar milk fraction. However, higher producing ewes can have both milk fractions within one peak, which results in a sharp rise or plateau phase. Generally, the milk flow pattern is specific to each animal (Labussiere, 1988). Furthermore, each modification to the standard milking routine could potentially result in a problem during milking, such as a disturbance of milk ejection associated with unfamiliar surroundings (Bruckmaier *et al*., 1993), poor milking routines or uncomfortable milking equipment (Hubert *et al*., 2018). For these reasons, milk ejection kinetics are a useful diagnostic tool during the milking process. To increase productivity during the milking process, milk yield (kg) (MF1) is a very easy trait to measure and utilize with automatic measuring devices. This trait has previously demonstrated high heritability and repeatability (Ilahi *et al*., 1998). Furthermore, this trait is significant because it can be recorded automatically in the parlour and has high correlation with peak flow rate (PFR) (0.92) and average milk flow (AFR) (0.85) in Alpine dairy goats (Ilahi *et al*., 1999). MF1 showed high repeatability (0.68) when estimating milking speed in Murciano-Granadina dairy goats (Blasco *et al*., 2016). Genetic correlations between milk flow and SCC were observed to be high in both Alpine and Saanen goats (0.63 and 0.39, respectively) (Palhiere *et al*., 2014). This could indicate that selecting for MF1 may indirectly select for animals with potentially high SCC as well. It is also one of the main factors explaining an animal's ability to adapt to the management practice of once daily milking (ODM) (Hassoun *et al*., 2016).

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Milking machine system and milking routines

Milking with heavily used liners (more than 3000 milkings) increases teat wall thickness, teat canal length and teat end wall area in Murciano-Granadina goats and teat wall thickness in Manchega sheep (Alejandro *et al*., 2014). On the other hand, the use of twisted liners during milking results in increased teat wall thickness and teat canal length in Murciano-Granadina goats. Such results were not observed in Manchega sheep, although all of the teat measurements were numerically higher after milking (Alejandro *et al*., 2014). Mid-line (ML) and high-line (HL) milking installations in sheep do not provide any differences in milk production, milk fractioning during milking, teat-cup fall-off, milking time (MT), SCC, milk composition or free fatty acids (Diaz *et al*., 2004). However, milk emission curves differ according to parlour milk line positions, in which milk flow appears earlier in the low-line (LL) than in the ML system. Thus, the position of the line used is an important factor when evaluating the milk flow curves. It is important to note that vacuum fluctuations in the ML and HL are greater than in the LL system. In Murciano-Granadina goats, more noticeable teat end vacuum fluctuations were observed in the ML compared to the LL milking system during milk flow (Manzur *et al*., 2012). The LL milking system in goats provides a smaller vacuum fluctuation and lower initial vacuum, which could be beneficial for teat and udder health. Even though acyclic vacuum fluctuations have previously been observed more frequently in the ML system, there was no incidence of increased liner slips, teat-cup fall-offs or changes in the teat end condition. The proportion of new IMI was similar in both systems, but appeared earlier in the ML compared to the LL system. Average milk flow and MF1 recorded in the milk meter 60 s after appearance of milk in the claw) were slightly lower in the ML compared to the LL system, but PFR and MT did not differ (Blasco *et al*., 2016). Moreover, the ML system slightly lowered machine milking fraction and increased machine stripping fraction. The stripping fraction is increased when the animal is not well-adapted to machine milking (indigenous breeds) or if the milking machine's parameters are not well adapted to the animal (Marnet and McKusick, 2001). Ewes entering the milking parlour in the first compared to the last milking group presented similar milk composition and SCC, but they differed in the milk flow kinetics parameters (shorter latency time, higher PFR, higher milk production and higher milk yield in the first 30 s and 60 s of milking) (Macuhova *et al*., 2017). One of the potential reasons for these differences could be stress felt during the milking process, which reduces ease of milking. Thus, the use of milk meters and ACR could be beneficial, as it would enable treatment of each individual ewe, which would reduce stressful conditions as much as possible. Interestingly, in this study, only the Lacaune breed compared to the Tsigai × Lacaune crossbreed and improved Valachian × Lacaune crossbreed showed differences in milk flow kinetics. This suggests that breeds under intensive selection are less stressed by machine milking than rustic breeds.

Pre-milking teat preparation

Pre-milking udder preparation is mainly recommended for improving sanitary status of milk collected or for flocks with high mastitis risks. However, it is potentially not worth the time spent when considering the short MT of small ruminants. Still, teat preparation can be recommended to initiate milk ejection, resulting in more efficient milk flow especially in non-specialized dairy breeds such as Dorset ewes (Geenty and Davison, 1982). Teat preparation of 30 s increased PFR and AFR and also significantly reduced MT in Alpine dairy goats (Basic *et al*., 2009). When milking ewes, the insertion of a support (Sagi hook) between the glands changed the pattern of the milk fractions during machine milking (Sagi and Morag, 1974). The Sagi hook enabled the collection of milk that usually remains in the gland cistern due to highly placed teats. Another solution to optimize milk collection is to adjust settings of the milking apparatus more accurately to the needs of the animal. High vacuum levels (>42 kPa) are often used to facilitate the opening of the teat sphincter and increase throughput in the parlour. However, this management practice may also result in severe machine-induced teat tissue damage. In a system with limited vacuum fluctuations with a light cluster (<300 g), dairy sheep could be milked with only a vacuum level of 28 KPa. This system resulted in differences in milk production, a limited effect on parlour throughput, and increased MT (Caria *et al*., 2013). Machine stripping fraction and teat end thickness after milking were lowest using a milking vacuum of 38 kPa compared to 44 or 50 kPa (Sinapis *et al*., 2006). For Lacaune dairy ewes, based on OT measurement and SCC, 180 pulsation/min and 36 KPa appears to be more efficient for better stimulation of the animals and to reduce climbing of the liner which increases stripping milk (Marnet *et al*., 1996). For goats, the recommended vacuum settings for milking in Europe are between 36 to 44 kPa (Le Du, 1989; Sinapis *et al*., 2000). The recommended pulsation rate was generally between 70 to 100 pulsation/min (Le Du, 1989; Sinapis *et al*., 2000). However, current recommendations are to use a higher pulsation frequency (120 pulsation/min) in high yielding animals such as Alpine and Saanen breed. With such so high pulsation rate, a pulsation ratio of 50% to 60% is generally used to minimize the impact on teat health status. At the end of milking, manual or machine stripping has been practiced for decades due to bad morphology prevalent in dairy ewes (high cisternal pouch and horizontally placed teats). However, with increasing capabilities to support larger milking intervals and milk accumulation in selected animal breeds, the milking process without stripping does not impact future milk secretion and total milk yield. Therefore, stripping could be omitted without risking udder health. As a consequence, this would save time when milking animals with desirable udder morphology, such as with East Friesian ewes (McKusick *et al*., 2003).

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Milking management and milking frequency

Saving time during milking appears to be a priority for many producers, especially when increasing flock size. Different management strategies were tested to reach this goal: mixed management of milking and suckling, three milkings in 2 days, deletion of one milking per week, and ODM during part of or the entire lactation (Marnet and Komara, 2008). When comparing once- to twice-daily milking, Murciano-Granadina and Alpine dairy goats decreased in milk production by 21% and 18%, respectively (Salama *et al*., 2004). In Murciano-Granadina dairy goats, cisternal milk fraction was also positively correlated to total milk yield when milked twice-daily was practiced. This reveals the importance of cisternal size for all milking intervals, and especially in long milking intervals (24 h ODM; Salama *et al*., 2004). Primiparous Murciano-Granadina goats have a smaller cisternal size and cisternal milk fraction than multiparous goats. This indicates that primiparous goats milked once-daily would display higher milk yield losses compared to multiparous goats. However, this hypothesis was not verified in high-yielding Alpine Goats in a study whereby parity and cisternal size were revealed to not affect milk yield losses due to ODM (Komara *et al*., 2009). This suggests a relationship between cisternal capacity and milk yield with the level of milk production of the breed. In Tinerfena dairy goats, ODM resulted in only a 6% reduction in milk production, which was contributed to the breed's higher udder volume and udder depth (Capote *et al*., 2006). This study suggested that baggy udders, while not being the most suitable for machine milking, could be an interesting management strategy for ODM. Co-selection for better udder morphology and ODM adaptability appears to be critical for avoiding a temporal drift in udder morphology. In dairy ewes, ODM is less commonly utilized, but an increase in cisternal capacities could help to better adapt to this management option. A recent long-term study was performed in Lacaune dairy ewes, during which the first month of lactation was managed in a dual-purpose system of ODM and free suckling (Hassoun *et al*., 2016). Results from this experiment revealed a 14% average decrease in milk production (between 8% and 17% in multiparous ewes, and 6% and 21% in primiparous ewes) over sequential lactations. Furthermore, no negative effects on udder morphology were observed in subsequent lactations in the primiparous ewes. Somatic cell count was not affected by these management strategies, confirming that the mammary gland will adapt without major consequences such as udder inflammation or mastitis (Hassoun *et al*., 2016). Losses during ODM between 5% and 51% were observed in ewes and between 6% and 40% in goats (Marnet and Komara, 2008). Higher milk production losses were observed when ODM management was applied immediately after lambing/kidding. It was therefore recommended for ODM to be applied in small ruminants only after a short period of continuous milking and stimulation. As observed previously in goats and ewes, both external and internal morphology is significantly linked to ODM ability, and co-selection is required to avoid degradation of udder morphology over time. A point that must be emphasized is that an increase in intra-mammary pressure induces higher milk flow rate in ODM animals. Currently, there are no studies testing different milking settings related to this management practice.

Automatic cluster removal

There are several automatic devices utilized on dairy farms, such as ACR, milk meters, electronic identification and sort gates. These devices have been shown to reduce labour, improve udder health and offer exact data on milk production through management software used by the farmer. These automatic devices have been primarily used in dairy cows. However, in the last couple of years, there has been a greater demand to use such equipment with sheep and goats (Alejandro, 2016). The most important device related to the milking routine is the ACR. This technology can also be combined with a milk meter. The use of ACR in dairy cows reduces overmilking, improves teat condition and udder health, saves labour and improves the milking routine. However, it has a high cost and also requires maintenance and a periodic reliability check (Rasmussen, 1993). It is important to state that the same take-off settings in two different ACRs will not result in similar milk flow at take-off compared to pre-set milk flow take-off settings. The different sensors, lengths of the hoses, vacuum and pulsation settings, and delay time (DT) settings, whereas is electronic, mechanic or count the slugs, are the reasons explaining this trend. The ACR component in the small ruminant is the automatic vacuum shut off system (AVSO; Alejandro, 2016) or the automatic vacuum cutting devices system (Bueso-Rodenas *et al*., 2014). These systems have the advantage of the cluster not being manually removed by the milker. As a result, this reduces MT per animal, maintains a uniform milk out, and overmilking is decreased. The AVSO systems are usually time- or flow-based with or without an ACR, and the system can also be coupled with an automatic pulsation stop device or automatic swing-over arms. The first time-based AVSO systems were used in the Lacaune breed and resulted in an average maximum MT of 2 to 3 min, depending on the stage of lactation, level of milk production and AFR. In newer parlours, there is the possibility of using two detachment times with the AVSO system. Flow-based systems must be equipped with milk meters to determine milk flow during the milking process. This AVSO type typically uses a cluster take-off milk flow ranging from 100 to 250 g/min according to manufacturer recommendations. This equipment utilizes two features: two terms: a minimum MT – time from cluster attachment to occurrence of the milk flow in the milk meter (usually 20 to 40 s) and DT (the time between reaching take-off milk flow until the vacuum is shut off). The DT time is a critical value in the milk flow-based ACR. Depending on a particular animal, there are two possible milk flow cases, which are steep or mild after the threshold milk flow was

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reached. If the animal has a steep milk flow decrease, then the actual milk flow at take-off will be much lower. On the other hand, if the animal has a mild milk flow at take-off, then the take-off milk flow will be very close to the pre-set milk flow for the take-off. Moreover, DT is important if the milk flow returns to values that are above the threshold milk flow, a case in which the teat-cup should not be removed from the udder (Bueso-Rodenas *et al*., 2014). This is particularly important in animals that have a milk flow curve with two peaks, where the second peak means alveolar milk ejection milk. A recent study in Saanen goats, which tested an ACR detachment milk flow of 70 g/min and a DT of 10 s observed that the overmilking was reduced (Tangorra *et al*., 2010). Surprisingly, the milk yield was also significantly higher in the group utilizing this ACR setting compared to manual take-off. This result can be explained by the fact that the ACR system in the experiment utilized a retraction device maintaining the cluster during milking. This result highlights the importance of the position and adjustment of the cluster on the teats and udders for a good milking process (Tangorra *et al*., 2010).

In Alpine dairy goats, the use of ACR with a milk flow measuring device reduced costs by 33.5% and increased milking throughput by 130% (Tangorra *et al*., 2007). The two highest ACR take-off settings of 500 and 200 g/min were applied during milking of the Alpine dairy goats compared to the Saanen goats. When these two ACR settings were applied, no change in total milk production and PFR were observed compared to manual take-off, but AFR was significantly higher and milking duration was decreased with 500 g/min (500 *v.* 200 g/min, 20 s; 500 g/min *v.* manual take-off, 43 s). Teat congestion and temperature parameters (teat and udder) were significantly higher with manual take-off compared to both ACR settings, suggesting less tissue compression due to machine milking. In France an unknown problem in dairy goats was recently discovered showing unbalanced udders, resulting in animals that needed to be culled from the flock because of the higher risk of intra-animal half-udder overmilking. A field study conducted in France confirmed that the number of goats with unbalanced morphology is frequent (21.7%) and that unequal milk flow (between udder halves) exists in 16.9% of goats. The ACR system with a higher milk flow threshold, due to stopping the vacuum when the first half udder is emptied, could be helpful for to indirectly selecting animals without such problems. Problems of morphological and functional imbalance could partially explain the lack of observed effect of ACR on udder health (SCC) in small ruminants despite the clear reduction of teat compression already described. Longer studies examining the risk factors of mastitis should be considered to address this point. In Manchega dairy ewes, the highest machine milk fraction was achieved with a threshold milk flow of 150 g/min and DT of 20 s. Milking duration was the shortest when milk flow threshold applied was 200 g/min and DT of 10 s (Bueso-Rodenas *et al*., 2014). Detachment when milk flow reached a level lower than 150 g/min did not provide better emptying of the mammary gland in Manchega dairy ewes. Interestingly, when a DT of 20 s was examined in both low- and high-yielding Manchega dairy ewes, the hand stripping fraction was decreased compared to a DT of 10 s. When both sets of ewes were tested, a difference in the proportion of units falling off was detected, ranging from 1.5% in higher producing animals in the second test compared to 10.5% in the low-producing Manchega dairy ewes in the first test. It seems likely that the period of low flow was longer in lower producing animals, which resulted in a higher fall-off percentage. Shorter milking duration per row was observed in Manchega dairy ewes in an ACR treatment with a detachment milk flow of 150 g/min and DT 20 s. This treatment reduced MT by 18 s in the morning and up to 48 s in the evening milking compared to manual teat-cup removal (Bueso-Rodenas *et al*., 2015). Machine milking settings where ACR had a detachment milk flow of 200 g/min and DT 10 s saved even more time, which ranged from 64 to 78 s during the morning and evening milking, respectively. In the same experiment, when ACR treatments were applied, limited vacuum drops in the short milk tube and significantly better teat condition was observed compared to manual teat-cup removal. These results can be explained by longer milking duration that could increase the mouthpiece chamber vacuum during low milk flows or in unbalanced udders (Poulet, 2016).

Conclusion and recommendations

This review supports the notion that the milking routine in goats and ewes should consist of teat-cup attachment, the main milking phase and ACR detachment. Aspects of the routine could be time- or milk flow-based. Goats experiencing increased SCC should receive pre-milking teat preparation. Pre-milking teat preparation results in better milking characteristics, but requires an increase in labour. Udder morphology related to machine milking in goats and sheep requires a better teat angle placement (position and angle) that will prevent milk accumulation in the teat cistern at the end of milking. Moreover, udder halves should not be unbalanced. With regards to current milking management, a simplified milking system utilizing an extended milking interval is more often, making co-selection for milking ability and milking performance a priority. In addition, the recommended machine milking settings are: ~ 38 kpa of vacuum for 100/120 to 180 pulsation/min, respectively, for goats and ewes. Omitting stripping does not negatively affect milking and is a good time saving strategy where ACR feature needs to be used with higher settings than recommended by the manufacturer. Cluster detachment can be time- or flow-based, but increased milking efficiency is achieved when flow-based information is used. The current ACR recommended take-off settings for goats are: 200 g/min + 10 s DT for a long decreasing phase and two plateau curves or 500 g/min + 5 s DT for a short decreasing phase and one plateau curve. Recommended ACR take-off settings in ewes are: 150 g/min +10 s DT for a long decreasing phase and 200 g /min + 5 s DT for a short decreasing phase.

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