Specific aspects of milk ejection in automatic milking system

R.M. Bruckmaier, J. Macuhová & H.H.D. Meyer

Institute of Physiology, Technical University Munich, FML,
Weihenstephaner Berg 3, D-85350 Freising-Weihenstephan, Germany
E-mail: bruckmaier@weihenstephan.de

Summary

Milking routines in automatic milking systems (AMS) differ from those in conventional milking. While milking intervals are constant and teat cups are attached simultaneously in conventional milking, in AMS milking intervals are variable and attachment of teat cups can be sequentially delayed. Experiments were performed to test effect of pre-milking teat cleaning, of different milking intervals in different lactational stages, of delayed teat cup attachment and individual teat cup removal on oxytocin release, milk ejection and milk removal. Teat cleaning caused oxytocin release and induced milk ejection. Lag time from start of teat stimulation until start of milk ejection increased with decreasing milking interval and was longer in late than in early lactation. Sequentially delayed attachment of teat cups every 20 s or every 60 s did not reduce oxytocin release. However, total interruption of milk ejection for 2 min between prestimulation and start of milking resulted in transiently decreasing oxytocin concentration and increasing amounts of residual milk. The stimulatory effect of single teat cups during sequentially delayed attachment is sufficient to maintain adequate oxytocin release and maximum milk ejection.

Key words: *Automatic milking systems, milk ejection, oxytocin, teat stimulation.*

Introduction

Milking routines in automatic milking systems (AMS) differ considerably from those in conventional milking. In AMS milkings are performed throughout the day and the visits of the AMS are voluntarily determined by the cow albeit it is up to human control if milking is performed during these visits. The time needed for teat cup attachment in AMS is usually longer (up to several minutes) than cluster attachment by the milker in conventional milking. Furthermore, the start of teat cup attachment after the end of teat cleaning in the AMS can be delayed due to technical reasons.

In multi-box systems, this delay cannot be avoided because the cow has to walk to another box between cleaning and milking (Macuhová & Bruckmaier, 2000).

Oxytocin (OT), the essential hormone to induce milk ejection, is released into circulation in response to tactile (i.e. manual or mechanical) teat stimulation. The lag time from the start of stimulation until the onset of milk ejection usually lasts 1 to 2 min (Bruckmaier *et al*., 1994). Timing of release of OT and milk ejection before the start of milk removal can be crucial for succeeding milking performance. Delayed milk ejection at the start of milking is indicated by bimodal milk flow curves, i.e. transiently reduced or interrupted milk flow after removal of the cisternal milk before alveolar milk is available (Bruckmaier and Blum, 1996).

The intention of this paper is to review the current knowledge including recent results on milk ejection and milk removal in AMS milking routines after different milking intervals and lactational stages, during sequentially or totally delayed teat cup attachment after udder preparation.

The stimulatory effect of pre-milking teat cleaning

Alveolar milk ejection at the beginning of milking is essential for fast and complete milk removal. In conventional milking tactile teat stimulation (manual or mechanical by the liner) before the start of milking is often performed to avoid delayed milk ejection (Bruckmaier and Blum, 1998). In AMS teats are cleaned by water, towel or brush. This cleaning period is ideal for prestimulation, provided that the type of teat and udder cleaning induces sufficient release of OT to induce milk ejection.

We have investigated the stimulatory effect of cleaning by rolling brush or towels. Brushing of teats and udder for 60 s induced release of OT and hence alveolar milk ejection (Macuhová and Bruckmaier, 2000). Similarly, teat cleaning by rolling towels induced milk ejection (Bruckmaier, unpublished data). Thus, mechanical teat cleaning of various AMS types causes release of OT and induces milk ejection. However, duration of cleaning must be long enough to provide a sufficiently long period of pre-stimulation without the removal of milk.

Effects of lactational stage and milking interval on milk ejection

Only the cisternal milk, stored in teat and gland cisterns and in large milk ducts, is removed by the milking vacuum already before milk ejection. This fraction usually amounts to less than 20 % of the total milk after a milking interval of 10-14 h (Pfeilsticker *et al*., 1996). The alveolar milk fraction must be actively shifted into the cisternal cavities by milk ejection to be available for milking. Towards the end of lactation cisternal milk yield and fraction decreases with reduced milk production and often becomes close to zero (Pfeilsticker *et al*., 1996). A similar effect is to be observed after short milking intervals. Until few hours after milking almost no cisternal milk is present (Knight *et al*., 1994). Milk ejection is delayed

towards the end of lactation (Mayer *et al*., 1991). A similarly delayed milk ejection as in late lactation is observed after short intervals from previous milking. Intervals shorter than 8 h usually don not occur in conventional milking systems but are common in AMS milking. It could be shown that the lag time until occurrence of milk ejection in response to teat stimulation is a function of degree of udder filling. Milk ejection was delayed if less milk was stored in the udder, independent if due to reduced production in late lactation or due to short interval from previous milking (Bruckmaier and Hilger, 2001).

The lag time until occurrence of milk ejection does not depend of the amount of stored milk per se. Thus, milk ejection occurred after a similar lag time in animals of different production levels at the same stage of lactation (Wellnitz *et al*., 1999). In this case the degree of filling of the individual udder was similar, because lower producing udders had lower storage capacity. We assume that in partially filled alveoli more contraction of the myoepithelial cells and therefore more time is needed until milk is ejected in milk ducts and cistern. Therefore, at low degree of udder filling, i.e. after short intervals from previous milking and in late lactation, milk ejection occurs later (Bruckmaier and Hilger, 2001). If no specific pre-stimulation is applied, cisternal milk is removed during the lag time until occurrence of milk ejection. Because cisternal milk yield is particularly low after short interval from previous milking (Knight *et al*. 1994) and in late lactation (Pfeilsticker *et al*. 1996), i.e. at low udder filling, the negative effect of delayed milk ejection is even enhanced by low amounts of cisternal milk (Bruckmaier and Hilger, 2001). Milking empty teats is the consequence. Therefore, the duration of teat cleaning in AMS should be adapted to the actual interval from previous milking, under consideration of the lactational stage of each individual cow.

Delayed teat cup attachment and interruption of teat stimulation

Experiments were performed in a conventional parlour to simulate AMS milking routines (Bruckmaier *et al*., 2000). Effect of sequential teat cup attachment and delayed teat cup attachment after end of pre-stimulation on OT release and amounts of residual milk was tested. Sequentially delayed attachment of teat cups every 20 or every 60 s did not reduce OT release. Stimulation of less than four teats has been shown to be sufficient to maintain OT release and alveolar contraction, i.e. sequential attachment of teat cups does not have negative effects on milk ejection and milk removal. However, total interruption of teat stimulation (delayed of teat cup attachment) for 2 min between pre-stimulation and start of milking resulted in transiently decreasing OT concentration and increasing amounts of residual milk.

After interruption of teat stimulation the transient decrease of intramammary pressure was compensated by renewed stimulation (Bruckmaier, 2000). In confirmation of this finding we have demonstrated during experiments in a multi-box AMS that negative effects on milk

removal of interrupted milk ejection between teat cleaning and teat cup attachment are avoided, if milk ejection is newly induced after the interruption by a pre-stimulation before milk removal starts (Macuhová and Bruckmaier, 2000).

Effects of individual teat cup removal

In most AMS teat cups are removed at the end of milk flow in each individual quarter. The advantage is that overmilking of single quarters can be avoided. On the other hand it may be assumed that the reduced stimulation of less than 4 teats causes reduced release of oxytocin and therefore incomplete emptying of the quarters which are still milked. We could, however, show that the quarters in which teat cups were last removed had the smallest amounts of stripping and residual milk, albeit differences were not significant (Bruckmaier *et al*., 2000). Obviously stimulation of only one teat causes.

Conclusions and indications for practical AMS milking

The presented results demonstrate that teat cleaning devices in AMS are suitable for pre-stimulation. Pre-stimulation seems to be even more important in AMS than in conventional twice daily milking, because very short intervals between milkings can occur. As a consequence, late occurrence of milk ejection and concomitantly low amounts of cisternal milk require long stimulatory periods before the removal of milk to avoid milking of empty teats. Sequentially delayed attachment of teat cups and quarter-specific removal of teat cups at the end of milking seem to be without negative consequences for milk ejection. Delayed teat cup attachment after pre-stimulation cannot be avoided in multi-box AMS. Negative effects on milk ejection and milk removal are abolished if a further pre-stimulation is applied before milk removal is started. In summary, AMS can fulfil the physiological requirements of dairy cows to induce milk ejection as a prerequisite for complete milk removal.

References

Bruckmaier, R.M. & J.W. Blum, 1996; Simultaneous recording of oxytocin release, milk ejection and milk flow during milking of dairy cows with and without prestimulation. Journal of Dairy Research 63, 201-208.

Bruckmaier, R.M. & J.W. Blum, 1998; Oxytocin release and milk removal in ruminants. Journal of Dairy Science 81, 939-949.

Bruckmaier, R.M. & M. Hilger, 2001; Milk ejection and milk fat content in dairy cows at different degrees of udder filling. Journal of Dairy Research (in press).

Bruckmaier, R.M., S. Michelet, J. Macuhová, & H.H.D. Meyer, 2000; Ocytocinfreisetzung und Milchejektion unter besonderer Berücksichtigung der Melkroutine in automatischen Melksystemen. Proceedings of the 14th Tagung der DVG-Fachgruppe Physiologie und Biochemie, München 3-4 April 2000

Bruckmaier, R.M., D. Schams & J.W. Blum, 1994; Continuously elevated concentrations of oxytocin during milking are necessary for complete milk removal in dairy cows. Journal of Dairy Research 61, 323-334.

Knight, C.H., D. Hirst & R.J. Dewhurst, 1994. Milk accumulation and distribution in the bovine udder during the interval between milkings. Journal of Dairy Research 61, 167-177.

Macuhová, J. & R.M. Bruckmaier, 2000. Oxytocin release, milk ejection and milk removal in the Leonardo multi-box automatic milking system. In: Hogeveen, H., Meijering, A. (Eds.), Proceedings of the International Symposium "Robotic Milking", Lelystad, The Netherlands, 17-19 August 2000, 184-185.

Mayer, H., R.M. Bruckmaier & D. Schams, 1991; Lactational changes in oxytocin release, intramammary pressure and milking characteristics in dairy cows. Journal of Dairy Research 58, 159-169.

Pfeilsticker, H.U., R.M. Bruckmaier & J.W. Blum, 1996; Cisternal milk in the dairy cow during lactation and after preceding teat stimulation. Journal of Dairy Research 63, 509–515.

Wellnitz, O., R.M. Bruckmaier & J.W. Blum, 1999; Milk ejection and milk removal of single quarters in high yielding dairy cows. Milchwissenschaft 54, 303-306.