

# THE PURPOSE OF THE MILKING ROUTINE AND COMPARATIVE PHYSIOLOGY OF MILK REMOVAL

Debora A. Costa and Douglas J. Reinemann  
University of Wisconsin-Madison Milking Research And Instruction Lab

Paper Presented at the 2004 meeting of the National Mastitis Council

## Introduction

There are now, and have always been, three primary purposes of the pre-milking routine:

- Sanitation
- Abnormal milk / Clinical Mastitis Detection
- Stimulation

These objectives must also be achieved in a way that is friendly to the cow. Recent research has emphasized the importance of the human/cow interaction in the success of the milk let down response and the milking process.

Producers of high quality milk know that a consistent method of premilking udder hygiene and the uniform attachment of properly functioning milking machines are important. The objective of milking management is to ensure that teatcups are applied to calm cows with visibly clean, well-stimulated teats, milk is rapidly and efficiently harvested and milking units are removed when milking is completed. The application of a post milking sanitizer has also been shown to be effective in reducing mastitis infections.

The seven habits of highly effective milking routines identified by Ruegg et al., (2000) are summarized as:

1. Cows are calm and clean before milking.
2. Cows are grouped by infection status (or milked in a way to avoid transfer of pathogens by the milking machine).
3. A consistent premilking cow prep is used.
4. Teats are clean and dry before attaching milking units.
5. Milking units are attached properly (At the correct time, without excessive air admission and adjusted to hang evenly on all four quarters.
6. Milking units are promptly and properly removed at the end of milking
7. Cows are managed post-milking (Application of post milking sanitizer kept standing to allow teat canals to close).

## *Sanitation*

The pathogen concentration in or near the environment of the teat orifice appears to have **THE** dominant influence on rate of new mastitis infection (Mein et al., 2004). It is clear from both field studies and controlled research that the majority of new mastitis infections occur when teat ends are exposed to pathogens in the housing area. Estimates of the number of new infections that occur in the animal housing area range from 80 to 94 percent. Sanitation of the housing area thus has the overriding influence on the mastitis infection rate.

However, sanitation of teat ends at milking helps to remove manure, mud and pathogens that have accumulated at the teat end before milking and reduce the number of pathogens that are deposited on liners and could be transferred to other cows. The removal of pathogens from the teat skin twice or three times per day will also presumably reduce the risk of infection between milkings. The milking process also plays a role in the removal of pathogens that have become trapped in the keratin lining the teat canal

and thus plays an important role in reducing the risk of mastitis infection. These points are illustrated by the high rate of mastitis infections that occur during the dry period when teats are not cleaned regularly and the keratin lining of the teat canal is not being removed and replaced. The mechanism of bacteria transport into the teat sinus during the dry period has not, as yet, been fully explained.

### ***Abnormal Milk and Clinical Mastitis Detection***

There is considerable debate in the dairy community on the need to practice fore stripping. While there is no hard evidence available, dairy professionals estimate that fore stripping is not uniformly practiced either in Europe, where it is required by law, or in the rest of the world.

If teat sanitation requirements are being met it is also likely that the tactile stimulation is adequate to produce the milk letdown response in the majority of cows. Perhaps the most important reason to fore-strip cows is to detect abnormal milk and other signs of clinical mastitis. One way to reduce the transfer of contagious organisms from cow to cow is to establish a milking order in which infected cows are milked last (or with a designated milking unit). Infected cows must be identified in order to implement this practice. Identification of clinically infected cows and diversion of this milk from the bulk tank may also be a critical element in maintaining bulk tank somatic cell counts in a desirable range on some farms. Examination of udders and foremilk is the quickest way to identify infected cows and may be the only method of detection on many farms.

Another benefit of requesting that milkers fore-strip cows is to improve the odds that major debris will be removed from teats and that some tactile stimulation will occur as part of the pre milking preparation process.

### ***Stimulation***

The milking machine is a remarkably effective stimulation device. The tactile stimulation provided by the machine is comparable to calf suckling or hand stimulation. However, the milking machine also applies physiological stress to the teat skin and tissues. The affects of these physiological stresses become increasingly undesirable as the machine is applied to cows for longer periods because of increased milk yield in high producing cows, over-milking or a combination of these. Applying the milking machine to an udder that has already undergone the milk ejection reflex can reduce these undesirable effects.

It appears that 10 to 20 seconds of tactile stimulation is sufficient to elicit oxytocin secretion in high producing cows (Ruegg et al., 2000). The lag time from start of tactile teat stimulation until full milk ejection ranges from 60 to 120 seconds and depends on the degree of udder filling, which, in turn, depends on the interval between milkings and the stage of lactation (Bruckmaier, 2001). This lag between oxytocin release and milk ejection is accounted for by the time required to transport the hormone from the brain to the udder and for the alveoli to fully contract. Oxytocin has half-life of approximately 1.5-2 minutes (Nickerson, 1992). These relationships have given rise to recommendations for optimal prep-lag times (Rasmussen et al., 1992; Reneau and Chastain, 1995).

According to these time relationships the optimal application of manual stimulation would include 10 to 20 seconds of tactile stimulation at the point of first contact with the cow, followed by unit attachment 60 to 120 seconds after this first contact. Tactile stimulation applied immediately before milking unit attachment is not likely to produce significant added benefit for stimulation. To make the best use of the manual stimulation the first contact with the cow should include application of pre-dip and manipulation of the teats to 1) remove debris and 2) fore-strip to detect abnormal milk. Some cows may not express milk during this fore-stripping process, but the attempt will ensure that tactile stimulation has occurred on these animals that have a higher stimulation requirement and it is more likely that observation of the condition of each quarter for redness and inflammation will occur.

The following review of literature on the comparative physiology of milk removal will help to illuminate these points as well as provide the basis for adjusting milking routines for crossbred cows and other species.

### ***Comparative physiology of milk removal***

Milk is stored within two compartments of the mammary gland: the cistern (including teat and gland cistern and large milk ducts) and alveoli (small milk ducts and alveoli). The cisternal milk can be easily removed by sucking, hand or machine milking, without any previous stimulation. On the contrary, the alveolar milk can only be removed if milk ejection has occurred. Tactile stimulus on the mammary gland activates a neuroendocrine mechanism resulting in the release of oxytocin into the blood stream. Oxytocin causes the contraction of the myoepithelial cells that surround the alveoli, forcing the expulsion of the milk into the cisternal compartment (Bruckmaier and Blum, 1998). There are wide species differences in the physiology of milk ejection reflex (Ellendorff et al., 1982).

The milk ejection reflex is an instinctive reflex that is not under the conscious control of the animal. Suckling, hand milking and machine milking are known to cause sufficient tactile stimulation to induce milk ejection; although the literature reports differences in the intensity of stimulation caused by suckling and milking machine.

For instance, it has been shown that suckling has either stronger (Bar-Peled et al., 1995; Samuelsson and Svennersten-Sjaunja, 1996 and Lupoli et al., 2001), weaker (Akers and Lefcourt, 1982) or similar (de Passilé et al., 1997; Tancin et al. 2001; and Negrão and Marnet, 2002) effect in stimulating the milk letdown compared with cows milked by machine without the presence of the calf. Nevertheless, most authors (Akers and Lefcourt, 1982; de Passilé et al., 1997; and Tancin et al. 2001) agree that there is a higher oxytocin release in response to suckling as compared with milking in the presence of the calf. In comparison with hand milking, machine milking resulted in a smaller release of oxytocin (Gorewit et al., 1992). The extents of hand stimulus effects are variable, possibly arising from inter-breed variation in the response to stimuli (Walsh, 1974).

Good pre-milking stimulation improved the milking performance of cows (higher peak and average milk flow rates and decreased milking time) compared with cows that received no stimulation (Hamann and Dodd, 1992). The work of Mayer et al. (1991) indicated that oxytocin secretion remained above the threshold required for milk ejection throughout lactation. However, Bruckmaier and Blum (1998) explained that, because of the reduced volume of milk stored in the udder at the end of lactation, full milk ejection usually takes longer to occur and pre-milking stimulation is more important during this period.

Feedback inhibitor of lactation (FIL) is a milk-borne protein synthesized by secretory cells which has an inhibitory action on the same cells, limiting then further milk secretion (Wilde and Peaker, 1990). FIL is only active in the alveoli, in contact with the secretory cells, and its effect is concentration dependent. The excess of residual milk due to incomplete milk ejection increases the concentration of FIL in the alveoli and decreases milk secretion. The distribution of milk between cisternal and alveolar compartment will influence the degree of feedback inhibition in different species (Knight et al., 1994).

A common mechanism of milk ejection seems to apply to the majority of species studied. However, there are species differences in the need or degree of oxytocin release at milking (Akers, 2002). For instance, two animal models are used to explain the different patterns of the milk ejection reflex. In the rabbit model, initial suckling by the litter induces the release of a single pulse of 20-50  $\mu\text{M}$  oxytocin and milk removal is completed in 2-5 minutes. In the rat model, multiple pulses of 0.5 to 1.0  $\mu\text{M}$  of oxytocin are released at intervals of 5-15 min throughout suckling periods of 30-60 min. The sow's milk ejection is similar to the rabbit model, whereas human and ruminants' milk ejection patterns are more similar to the rat model (Cross, 1977).

There are large differences in the proportion of total milk stored within the cistern among ruminant dairy species. In addition, the size of the cistern varies with milking interval (Ugarte, 1977). Specialized dairy

cows store less than 30% of the total milk yield volume in the cistern with a normal milking interval (Ayadi et al., 2003). In contrast, the cisternal fraction accounts for up to 75% in dairy goats (Marnet and McKusick, 2001), and in sheep it ranges more than 50% for dairy breeds (McKusick et al., 2002) to less than 30% for meat breeds (Caja et al., 1999).

It has been argued that milk ejection may not be essential for adequate milk removal in animals that store most of the milk in the gland cisterns (Cross, 1977; and Akers, 2002). Oxytocin release in goats occurs immediately after the start of stimulation, causing a tendency for immediate decrease in milk flow rate after unit attachment (opposite than in cows) according to Bruckmaier et al. (1994). Marnet and McKusick (2001) found that oxytocin-mediated milk ejection is of primary importance in small ruminants for the extraction of milk that is rich in fat. Although the cisternal compartment stores most of the milk produced in small ruminants, the alveoli retain the majority of the milk fat secreted, which can be only efficiently removed when milk ejection occurs (McKusick et al., 2002).

Buffalo cows store almost 95% of their milk in the alveolar compartment with the small cisternal capacity most prominent in the teat area. As a result, pre-milking stimulation is of extreme importance for milk ejection removal and milking units should only be attached after the initiation of the milk ejection response (Thomas et al., 2003). Milk ejection in buffalos also requires about 2 minutes of tactile stimulation and calf suckling is often used for this purpose when milking is by hand. However, the practice of using calves is not as common in herds where buffalo cows are machine milked in parlors (Svennersten-Sjaunja, 2000).

In camels, the presence of the calf is considered imperative for milk let down, and hand massaging is also used to enhance this response. Milk letdown in this species is easily noticeable after a short period of suckling (1.5 min) when the teats suddenly swell, becoming much larger than before. Milking needs to be performed soon after the teat- swelling, since the duration of the milk letdown response is also very short, approximately 1.5 min. Because of this fact, some authors have assumed that camels do not have mammary cisterns. It has been reported that camels are able to refill their udder in about 30 minutes after complete milking by hand, to suckle their calves (Yagil et al., 1999).

The pig possesses numerous mammary glands without cisterns. Ellendorff and Poulain (1984) reported that the nursing intervals occurred about every 45 min, and lasted for 8-40 seconds. A study of the milk ejection reflex in the sow found that the whole litter had to be suckling in order to elicit the milk ejection response, which occurred between 2 and 4 min from the onset of the period of initial massage of the udders (Ellendorff and Poulain, 1984). Today, it is known that the milk ejection can be induced by rubbing the front teats in some sows (Hurley, 2002).

Another difference in the milk ejection reflex among mammalian species is the influence of exteroceptive stimuli (evoked by sight, smell, and/or sound from the nurse young or the milking place). In lactating rats, rabbits and guinea pigs oxytocin is released only in response to tactile stimulation (“unconditioned” type of milk ejection reflex). On the other hand, it was shown that ewes responded with the release of oxytocin under conditions of exteroceptive and tactile stimulation (Fuchs et al., 1987). There are some indications that exteroceptive stimuli usually turn into “conditioned” milk ejection reflexes, especially when a regular milking routine is adopted (Hamann and Dodd, 1992).

Interestingly, audio stimuli in the form of calf calls were not clearly shown to cause oxytocin release and affect the rate of milk ejection in Holstein cows (Pollock and Hurnik, 1978). Similarly, Mayer et al. (1991) did not find any evidence indicating that conditioned oxytocin release is triggered by audio-visual stimuli. In contrast, Hurley (2002) argues that tactile stimulation of the teat is not essential for oxytocin release and subsequent milk ejection. Hurley’s data (2002) indicate that about 38% of cows release oxytocin by conditioned visual and auditory cues, such as the sights and sounds of the milking parlor.

Fuchs et al. (1987) suggested that species in which the tactile stimulus is the only means to trigger the oxytocin response is linked to little or no mammary cistern, whereas those who release oxytocin at the sight and smell of their offspring have such compartments.

### ***Stimulation Requirements For Milk Removal In Crossbred Cows***

*Bos taurus* cows have been more intensively selected for milk production than *Bos indicus* cows. In high yielding dairy breeds, suckling, a natural stimulation for milk letdown, has been successfully replaced by hand stimulation. Perhaps one of the consequences of genetic selection of *Bos taurus* cows was an alteration in the regulation of milk ejection (Tancin and Bruckmaier 2001). Since these cows were also selected for rapid milking and ease of milking, it has been suggested that they probably acquired a reduced dependence of the milk ejection reflex (Akers, 2002). In contrast, artificial milk removal through hands of unfamiliar people or milking machines is still not very well accepted in some *Bos-indicus* cows. The entire mechanism responsible for the inhibition of milk ejection in cows remains unclear (Tancin and Bruckmaier, 2001).

The release of oxytocin in the milk ejection reflex can be disturbed at central or peripheral level of the nervous system under practical conditions. Milking conditions such as suckling by alien calf, calf removal before milking, milking of cows in the presence of own calf, unknown milking place, can thus affect the regulation of milk ejection (Tancin and Bruckmaier, 2001).

In contrast with the specialized European dairy breeds, in which milk production in the second lactation is usually higher than the first, it was demonstrated that crossbred cows had a linear reduction in milk yield in successive lactations. The lactation length was also gradually shortened. (Alvarez et al., 1980). The authors suggested that this could be attributed to the “special behavior” of crossbred cows being milked without their calves.

Four milking strategies were applied to cows containing 50-75% of Holstein genetics, (1) milking without the presence of the calf, (2) suckling the calf before milking and separating the calf immediately afterwards, (3) tying the calf near the head of the cow throughout milking, (4) suckling the calf before milking and tying the calf near the head of the cow throughout milking. This experiment showed that an equivalent amount of saleable milk was obtained from cows stimulated by suckling before milking or by the simple presence of their calves during milking. The yield for these treatments was greater than the amount of saleable milk from the group of cows milked without calves. The authors also found that a considerable amount of milk is suckled after milking, even in cows that were stimulated by calves during milking, thus indicating that milk ejection at milking is not complete (Combellas et al., 2003).

A similar experiment applied three treatments to Zebu crossbred cows: (1) calves allowed to suckle for a short time before milking and afterwards tethered to the neck of the cow, (2) no suckling before milking but calves were tethered to the neck of the cow (physical contact), and (3) cows were able to see, smell and hear their calves without making physical contact. Each cow-calf pair rotated through the treatments a three times. Suckling plus physical contact led to the highest milk yield ( $P < 0.001$ ). Physical contact by itself also enhanced milk production, but to a lesser degree. (Orihuela, 1990).

Cows that have the genetic potential for milk production but receive a poor diet may have their udders incompletely filled, which could lead to a weaker milk ejection response. The major feed resource for dual-purpose cattle raised in the tropics is grasses with a varied degree of supplementation, which is sometimes only provided during the dry season. There is some evidence indicating that an udder that is not well filled may take extra time for occurrence of milk ejection. It has been suggested that the delayed milk ejection response at low levels of udder fill is probably a consequence of delayed response to the oxytocin in the mammary gland. In order to force milk out of an incompletely filled alveolus, it is necessary that more myoepithelial contraction occur, which will require more time, resulting in a delayed ejection of milk to the cisternal compartment (Bruckmaier, 2001).

Wellnitz et al. (1999) found that cows of European breeds at different production levels (> 45 kg/d and 25-30 kg/d) but similar stages of lactation, in which their udders are filled to the same level, had comparable patterns of milk ejection. It may not be possible to extrapolate these results to cows with *Bos indicus* genetics because their udder fill, at the same stage of lactation, may not be comparable to *Bos taurus* cows.

A study by Costa (2003) found no evidence that calf suckling increased milk flow rates (which would indicate enhanced stimulation) but did appear to be associated with a lower Somatic Cell count in Zebu-Holstein cows in Brazil. The elimination of calf suckling during milking simplifies the milking routine and results in significant labor savings. Nevertheless, suckling may still be recommended for those cows that have an aggressive behavior during milking. Genetic selection for temperament may have already reduced the benefits of using calves during milking and may continue to reduce or eliminate these benefits in the future.

## References

- Akers, R.M. Lactation and the mammary gland. Iowa State Press, p 54-56, (2002).
- Akers, R.M.; and Lefcourt, A.M. Milking and suckling induced secretion of oxytocin and prolactin in parturient dairy cows. *Horm. Behav.* 16: 87-93, (1982).
- Alvarez, F.J.; Saucedo, G.; Arriaga, A.; and Preston, T.R. Effect on milk production and calf performance of milking cross bred European/Zebu cattle in the absence or presence of the calf, and of rearing their calves artificially. *Trop. Anim. Prod.* 5: 25-37, (1980).
- Ayadi, M.; Caja G.; Such, X.; and Knight, C.H. Use of ultrasonography to estimate cistern size and milk storage at different milking intervals in the udder of dairy cows. *J. Dairy Sci.* 70: 1-7, (2003).
- Bar-Peled, U.; Maltz, E.; Bruckental, I.; Folman, Y.; Kali, Y.; Gacitua, H. and Lehrer, A.R. Relationship between frequent milking or suckling in early lactation and milk production of high producing dairy cows. *J. Dairy Sci.* 78: 2726-2736, (1995).
- Bruckmaier, R.M. Milk ejection during machine milking in dairy cows. *Livest. Prod. Sci.* 70: 121-124, (2001).
- Bruckmaier, R.M.; and Blum, J.L. Oxytocin release and milk removal in ruminants. *J. Dairy Sci.* 81: 939-949, (1998).
- Bruckmaier, R.M.; Ritter, C.; Schams, D.; Blum, J.W. Machine milking of dairy goats during lactation: udder anatomy, milking characteristics, and blood concentrations of oxytocin and prolactin. *J. Dairy Res.* 61: 457-466, (1994).
- Caja, G.; Such, X.; Ruberte, J.; Carretero, A.; and Navarro, M. The use of ultrasonography in the study of mammary gland cisterns during lactation in sheep. In: *Proceedings of the Sixth International Symposium on the Milking of Small Ruminants: Milking and milk production of dairy sheep and goats.* p. 91-93, (1999).
- Combellas, J.; Tesorero, M.; and Gabaldón, L. 2003. Effect of calf stimulation during milking on milk yield and fat content of *Bos indicus* x *Bos taurus* cows. *Livest. Prod. Sci.* 79: 227-232.
- Costa, D.A., Surveys of milking characteristics and milk quality of Brazilian crossbred dairy cows. Masters Thesis, University of Wisconsin-Madison, (2003).
- Cross, B.A. Comparative physiology of milk removal. In: *Comparative Aspects of Lactation.* Edited by Malcolm Peaker. *Symp. Zool. Soc. Lond.* 41: 193-210, (1977).
- de Passillé, A.M.; Rushen, J. and Marnet, P.G. Effects of nursing a calf on milk ejection and milk yield during milking. *J. Dairy Sci.* 80, Suppl. 1, p. 203, (1997).
- Ellendorff, F.; and Poulain, D. A means to assess nursing efficiency in the pig: the study of the milk ejection reflex. *Ann. Rech. Vét.* 15: 271-274, (1984).

- Ellendorff, F.; Forsling, M.L.; and Poulain, D. 1982. The milk ejection reflex in the pig. *J. Physiol.* 333: 577-594.
- Fuchs, A-R.; Ayromlooi, J.; and Rasmussen, A.B. Oxytocin response to conditioned and nonconditioned stimuli in lactating ewes. *Biol. Reprod.* 37: 301-305, (1987).
- Gorewit, R.C.; Svennersten, K.; Butler, W.R.; Uvnäs-Moberg, K. Endocrine responses in cows milked by hand and machine. *J. Dairy Sci.* 75: 443-448, (1992).
- Hamann, J.; and Dodd, F.H. *Milking Routines. Machine milking and lactation*, Edited by A.J. Bramley, F.H. Dodd, G.A. Mein and J.A. Bramley. Insight Books, p. 81-96, (1992).
- Hurley, W.L. *Lactation Biology ANSCI 308 - University of Illinois (lesson: Milk Ejection)*. Web-site: <http://classes.aces.uiuc.edu/AnSci308>, (2002).
- Knight, C.H.; Hirst, D.; and Dewhurst, R.J. Milk accumulation and distribution in the bovine udder during the interval between milkings. *J. Dairy Res.* 61: 167-177, (1994).
- Lupoli, B.; Johansson, B.; Uvnäs-Moberg, K.; and Svennersten-Sjaunja, K. Effect of suckling on the release of oxytocin, prolactin, cortisol, gastrin, cholecystokinin, somatostatin and insulin in dairy cows and their calves. *J. Dairy Res.* 68: 175-187, (2001).
- Marnet, P.G.; and McKusick, B.C. Regulation of milk ejection and milkability in small ruminants. *Livest. Prod. Sci.* 70: 125-133, (2001).
- Mayer, H.; Bruckmaier, R.; and Schams, D. Lactational changes in oxytocin release, intramammary pressure and milking characteristics in dairy cows. *J. Dairy Res.* 58: 159-169, (1991).
- McKusick, B.C.; Thomas, D.L.; Berger, Y.M.; and Marnet, P.G. Effect of milking intervals on alveolar versus cisternal milk accumulation and milk production and composition in dairy ewes. *J. Dairy Sci.*, 85: 2197-2206, (2002).
- Mein, GA, DJ Reinemann, N Schuring and I Ohnstad, 2004. *Milking Machines And Mastitis Risk: A Storm In A Teatcup*. Proc. 43rd annual meeting of the National Mastitis Council.
- Negrão, J.A.; and Marnet, P.G. Effect of calf suckling on oxytocin, prolactin, growth hormone and milk yield in crossbred Gir X Holstein cows during milking. *Reprod. Nutr. Dev.* 42: 373-380, (2002).
- Nickerson, S.C. *Anatomy and physiology of the udder. Machine milking and lactation*, Edited by A.J. Bramley, F.H. Dodd, G.A. Mein and J.A. Bramley. Insight Books, p. 63-66, (1992).
- Orihuela, A. Effect of calf stimulus on the milk yield of Zebu-type cattle. *Appl. Anim. Behav. Sci.* 26:187-190, (1990).
- Pollock, W.E.; and Hurnik, J.F. Effect of calf calls on rate of milk release of dairy cows. *J. Dairy Sci.* 61: 1624-1626, (1978).
- Rasmussen, M.D., E.S. Frimer, D.M. Galton, and L.G. Peterson. 1992. *The Influence of Premilking Teat Preparation and Attachment Delay on Milk Yield and Milking Performance*. *J. Dairy Sci.* 75:2131.
- Reneau, J.K., and J.P. Chastain. 1995. *Premilking Cow Prep: Adapting to Your System*. Proc. Regional Meeting of the Natl. Mastitis Council. pp 46.
- Ruegg, PL, MD Rasmussen and DJ Reinemann, 2000. *The Seven Habits of Highly Successful Milking Routines*. University of Wisconsin Extension, Bulletin A3725.
- Samuelsson, B.; and Svennersten-Sjaunja, K. Effect of suckling on the release of oxytocin in dairy cows and their calves. *Proceedings of the Symposium on Milk Synthesis, Secretion and Removal in Ruminants*. University of Berne, Switzerland, p.75, (1996).
- Svennersten-Sjaunja, K. The buffalo is important for milk production. *AgriBizChina* web-site: <http://www.agribizchina.com>, (2000).
- Tancin, V.; Kraetzl, W.D.; Schams, D.; and Bruckmaier, R.M. The effects of conditioning to suckling, milking and of calf presence on the release of oxytocin in dairy cows. *Appl. Anim. Behav. Sci.*, 72: 235-246, (2001).
- Tancin, V.; and Bruckmaier, R.M. Factors affecting milk ejection and removal during milking and suckling of dairy cows. *Vet. Med. – Czech* 46 (4): 108-118, (2001).
- Thomas, C.S.; Svennersten-Sjaunja, K.; Bhosrekar, M.R.; and Bruckmaier, R.M. Mammary cisternal size, cisternal milk and milk ejection in Murrah buffaloes. *J. Dairy Res.* (in press), (2003).

- Ugarte, J. Rearing dairy calves by restricted suckling. 10. Residual milk in cows suckling or not their calves after milking. Cuban J. Agric. Sci. 11: 253-262, (1977).
- Walsh, J.P. Milk secretion in machine-milked and suckled cows. Ir. J. Agric. Res. 13: 77-89, (1974)
- Wellnitz, O.; Bruckmaier, R.M.; and Blum, J.W. Milk ejection and milk removal of single quarters in high yielding dairy cows. Milchwissenschaft 54: 303-306, (1999).
- Wilde, C.J.; and Peaker, M. Autocrine control in milk secretion. J. Agric. Sci. 114: 235-238, (1990).
- Yagil, R.; van Creveld, C.; Abu-R'Kaik, G.; and Merin, U. Milk "let-down" in camels. J. Camel Prac. Res. 6(1): 27-29, (1999).