Babcock Institute for International Dairy Research and Development

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Dairy Essentials

21) PRINCIPLES OF MILKING

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MILKING IS A TEAM EFFORT BETWEEN THE COW, THE MACHINE AND THE OPERATOR (OR THE CALF)

Milking is the act of collecting milk after proper stimulation of a cow to release milk from the udder. Collecting milk from a cow involves much more than a mechanical extraction. Essentially, milking is a team effort in which the cow, the machine and the operator (or the calf) play critical roles. For milking to be rapid and complete, the cow must receive the proper signals from her environment. Once the milk ejection reflex is triggered, the milk is squeezed out of the alveoli by the myoepithelial (muscular) cells and forced into the duct system. Then, the action of the mouth of a calf, the hand of an operator or the claw of a machine can collect the milk that has drained into the gland and teat canal.

MILK EJECTION REFLEX

Activation of milk "let-down"

Most of the milk accumulates within the alveoli between milkings. The milk ejection reflex starts with the activation of nerves

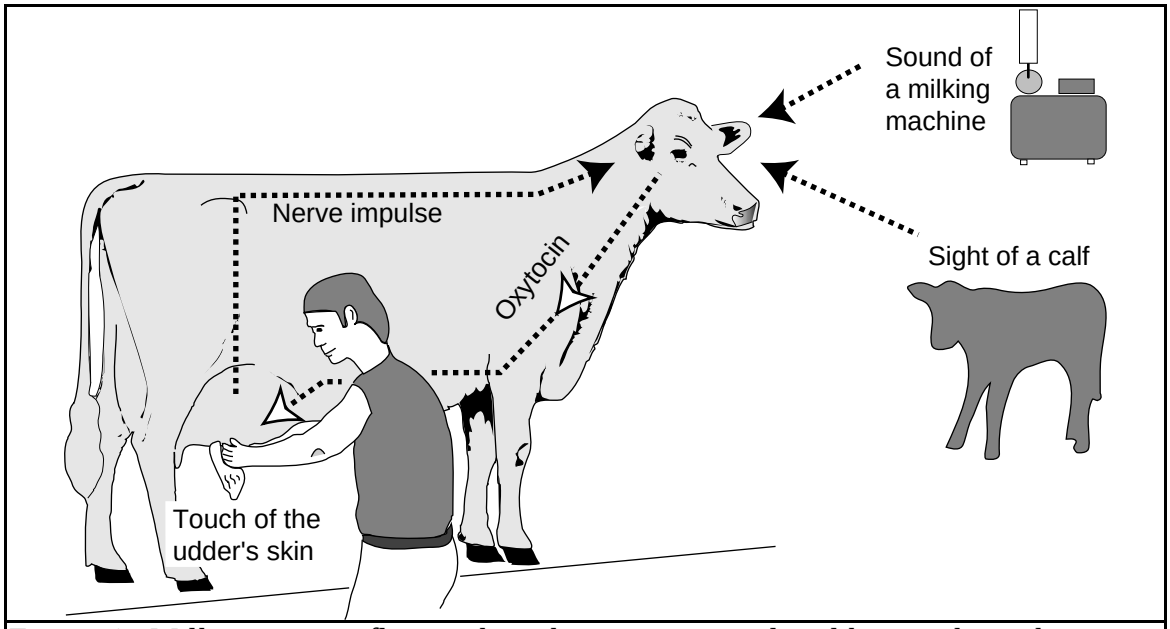

Figure 1: Milk ejection reflex—when the cow is stimulated by touch on the udder skin, the sound of a milking machine or the sight of a calf, nerve impulses pass to the hypothalamus in the brain. The hypothalamus stimulates the posterior pituitary gland to discharge oxytocin. Blood carries this hormone to the myoepithelial cells that surround the alveoli. The contraction of the myoepithelial cells forces the milk into the duct system and the gland cistern. Excitement or pain inhibit the milk ejection reflex.

whose impulses are interpreted by the brain (hypothalamus) to signal the cow that milking is imminent. One stimulus or a combination of the following external stimuli may initiate the milk ejection reflex (Figure 1):

- The physical touch of a suckling calf or that of an operator cleaning the teats (which are sensitive to touch and temperature);
- The sight of a calf (especially in *Bos indicus*—zebu-type cows);
- The sound of a milking machine.

Following these stimuli, the brain sends a signal to the posterior pituitary, a gland at the base of the brain, that releases the hormone oxytocin into the blood stream. The blood transports the oxytocin to the udder where it stimulates the contraction of the tiny muscles (the myoepithelial cells) surrounding the milk-filled alveoli. Contractions occur 20 to 60 seconds after stimulation. The squeezing action increases the intramammary pressure and forces the milk through the ducts to the gland and teat cistern.

The action of oxytocin only lasts for six to eight minutes because its concentration in the blood decreases rapidly. Thus it is critical to attach the teatcups (or begin hand milking) about one minute after initiating udder preparation. A delayed attachment reduces the amount of milk harvested. Although there may be a second discharge of oxytocin, it is usually less effective than the first one.

Inhibition of milk "let-down"

In certain situations, the milk ejection reflex can be inhibited. When this occurs, the milk is not released from the alveoli and only a small fraction can be collected. Nerve impulses are sent to the adrenal gland when unpleasant external events occur at milking (pain, excitement or fear). The hormone adrenaline, released by the adrenal gland, can constrict the blood vessels and capillaries in the udder. The decreased blood flow decreases the amount of oxytocin reaching the udder. In addition, adrenaline seems to inhibit the contraction of the myoepithelial cells in the udder directly. Thus the cow may not be milked rapidly and completely in the following situations:

- Inadequate udder preparation;
- Delayed attachment of teatcups (or initiation of hand milking) for minutes after preparing the udder;
- Unusual circumstances, that lead to pain (being hit) or fear (shouting, barking);
- Failure of the milking equipment to operate properly.

After the first calving, cows must be "trained" to the milking routine. The emotional upset that occurs in these cows may be enough to inhibit the milk ejection reflex. An injection of oxytocin for several milkings may help. However, this practice should not be done routinely because some cows may rapidly become dependent on the injection to elicit the milk ejection reflex.

COLLECTING MILK FROM THE UDDER

The opening at the tip of the teat is held shut by a group of circular muscles (sphincter). Normally, the milk in the gland and teat cistern does not leave the teat without an external force to overcome the strength of the sphincter muscles. However, the milk of some cows with strong milk ejection reflexes and/or weak sphincters may "leak" from the teat because the increased pressure in the udder at the time of milking overcomes the strength of the sphincter. A difference in pressure between the inside and outside of the teat is usually needed to open the sphincter and let the milk flow. Milk is routinely removed from the udder by (1) a suckling calf; (2) hand-milking; or (3) machine milking.

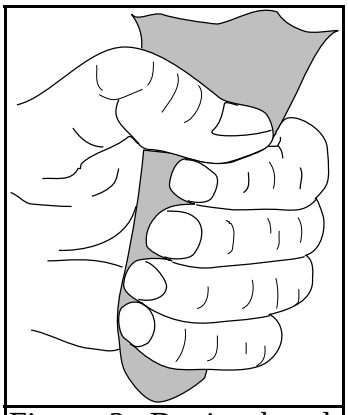

Figure 2: During hand milking, the pressure inside the teat becomes higher than outside the teat.

Hand milking uses pressure

In hand milking, the hand grasps the whole length of the teat. The thumb and forefinger pinch off the upper end of the teat as the other fingers squeeze inward and downward (Figure 2). The increased pressure inside the teat (relative to the atmospheric pressure outside the teat) forces the milk through the sphincter.

A suckling calf uses vacuum

A suckling calf or a milking machine use vacuum as opposed to pressure to extract milk from the gland and teat canal. When a sufficiently strong suction (vacuum) is applied at the tip of a teat, the pressure outside the teat is lower than inside and the milk is drawn out.

A suckling calf wraps its tongue and roof of the mouth around the teat. A vacuum is created at the tip of the teat when the jaws widen and the tongue retracts toward the throat. As a result, milk accumulates in the mouth. When the calf swallows the milk, its flow from the teat stops because the pressure inside the mouth returns to normal. Between 80 and 120 alternating suck and swallow cycles occur per minute.

The milking machine uses vacuum

The milking machine also uses vacuum to extract milk from the udder. The following paragraphs describe the action of the teatcup of a milking machine. For a more general description of the parts of a milking machine (see the *Dairy Essential* called "The Milking Machine"—number 4 in the "Lactation and Milking" series).

If the vacuum applied to a teat is too high or lasts too long, blood and body fluid will accumulate and the resulting congestion of the tissue will stop milk flow. In the case of a suckling calf, this problem does not occur because while the milk that accumulated in its mouth is swallowed, there is no pressure differential around the teat and normal

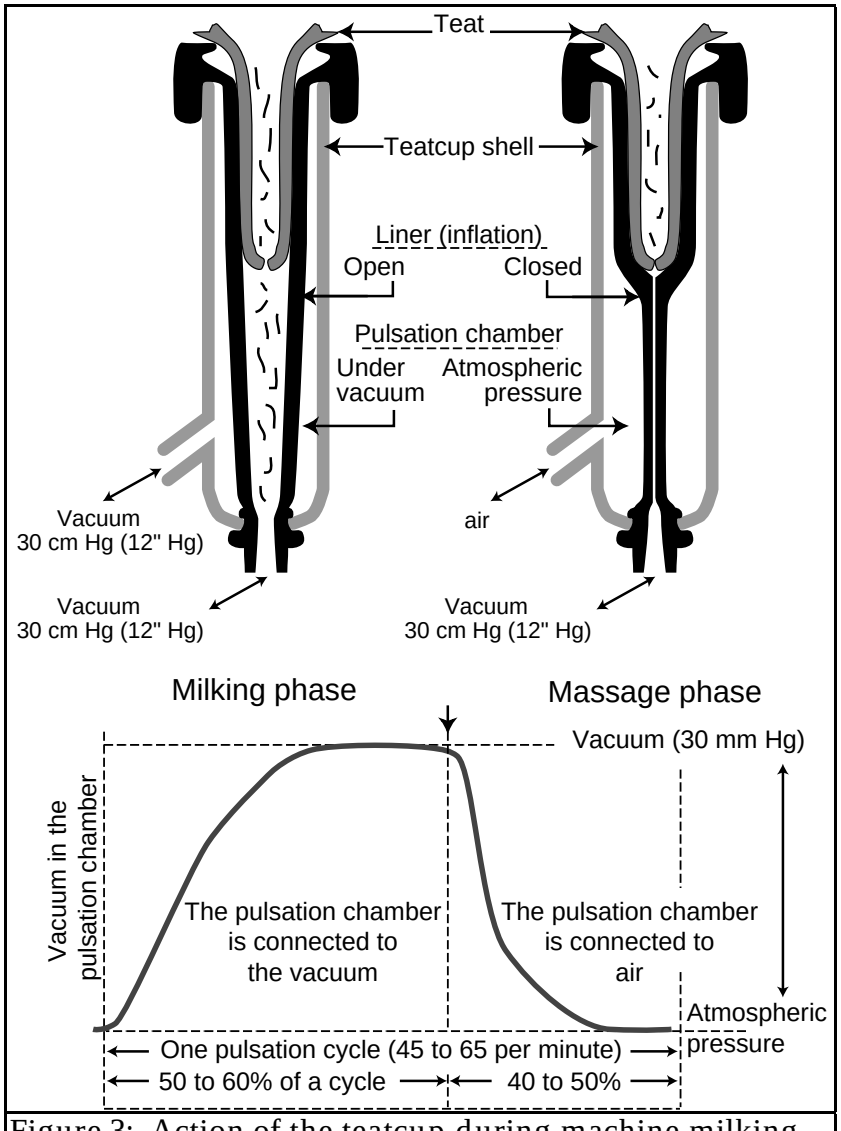

Figure 3: Action of the teatcup during machine milking.

blood circulation away from the teat is allowed. This process is referred to as the "massage" of the teat.

When a milking machine is used, the double chambered teatcup and the pulsator allow the teats to be subjected alternately to a vacuum (milking phase) and to atmospheric pressure (massage phase) (Figure 3). When air is removed from the pulsation chamber (area between the shell and the liner or inflation), the liner opens because the pressure inside the chamber and the pressure inside the vacuum line are the same. The vacuum at the end of the teat forces the milk out of the teat cistern into the line. However, when air is admitted inside the pulsation chamber the liner collapses beneath the teat (because the pressure inside the liner is lower than inside the pulsation chamber). During this period of "rest," the teat canal closes (but not the teat cistern), milk flow stops, and the body fluids that were "aspirated" in the tissue of the teat may leave. This massaging action of the teatcup during a pulsation cycle prevents fluid congestion and edema of the teat.

Typically, the liner of a milking machine opens and closes 45 to 65 times a minute (**pulsation rate**). In a pulsation cycle, the milking phase is usually equal or longer than the massage phase. The percentage of time of a pulsation cycle spent on each phase is referred to as the **pulsator ratio**. For example, a 60:40 pulsator ratio means that the vacuum is increasing or at maximum vacuum for 60% of the cycle and decreasing and/or at atmospheric pressure for 40 percent. For example, assuming a pulsation rate of 60 (one pulsation cycle per second), a the pulsator ratio of 60:40 indicates that the milking phase lasts 0.6 second and the massage phase lasts 0.4 second.