MILK SECRETION AND MILKING MACHINES

For the student to understand the milking operation, it is necessary to understand the internal anatomy of the udder and the physiology involved in milk secretion and milk letdown.

INTERNAL ANATOMY OF THE UDDER-THE RATHWAY OF SYNTHESIZED MILK

The udder of a cow is divided into four separate quarters. The fore quarters are usually about 20% smaller than the rear quarters, and each quarter is independent of the other three (Figure 13-1). To review the basic internal anatomy of one of the quarters of the udder, we will follow the path of milk front the point of synthesis to the end of the teat.

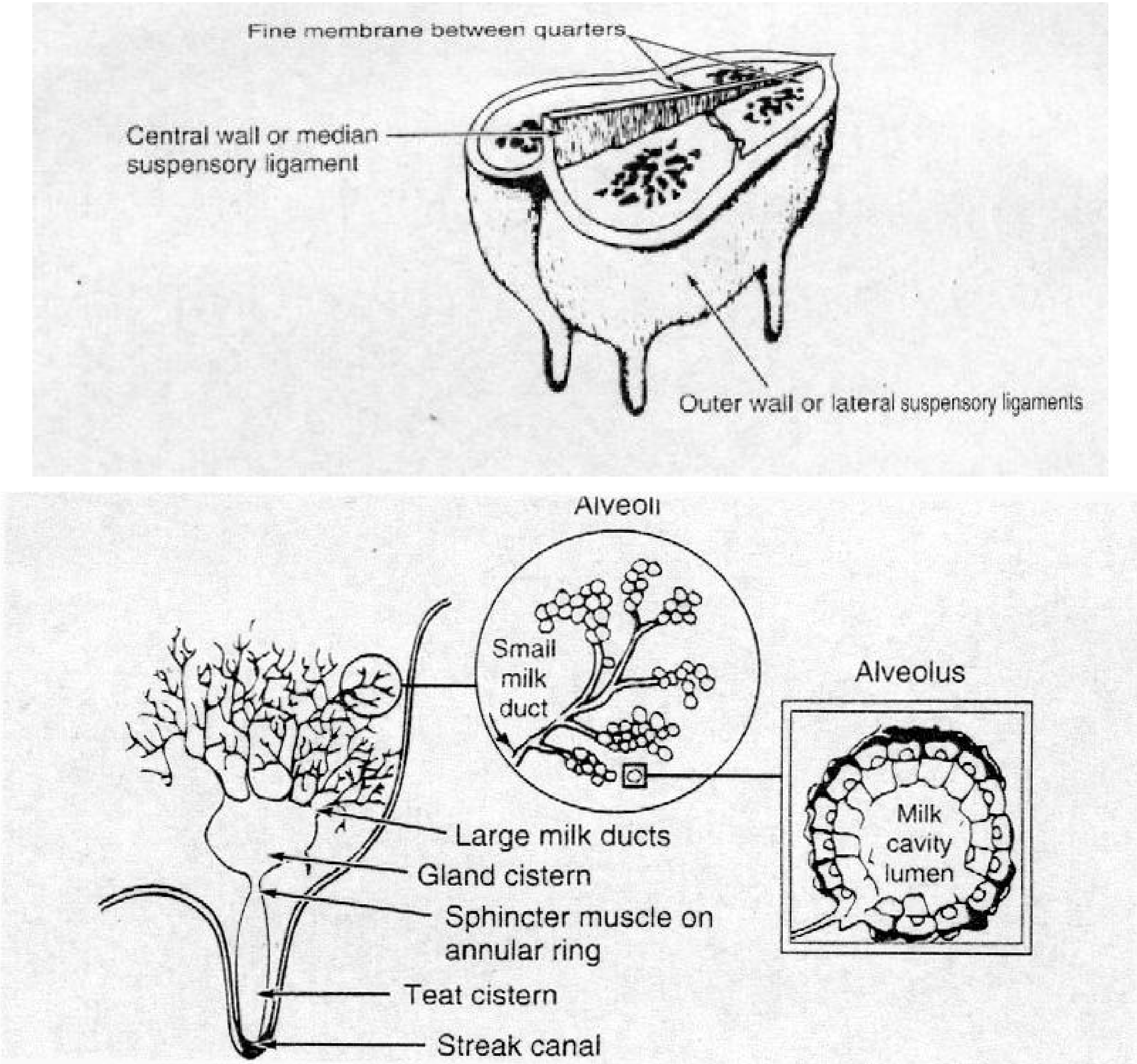


FIGURE1: The udder is divided into four separate quarters, each independent in its milk-producing function.

Individual secretary "grape-like" units called *alveoli* secrete milk. These small units range from 0.1 to 0.3 mm. In diameter and consist of an inner lining of epithelial cells that surround a hollow cavity, the *lumen*. The epithelial cells actually secrete the milk by taking raw materials from the blood supply and synthesizing them into milk. The synthesized milk is secreted into the lumen of the alveolus, which full contains about 1/5 of a drop of milk. A group of such alveoli in a "grape-like" cluster is termed a *lobule*. The lumen of each alveoli connects directly with the stem of the cluster of *tertiary* duct to another prevents complete drainage of milk. The primary ducts carry the milk to the *gland cistern*. The gland cistern drains through the *annular ring* of the upper teat into the *teat cistern* or cavity inside the teat. Milk is prevented from leaking from the teat cavity by the action of a *sphincter muscle,* which surrounds and closes the steak canal. The

steak canal is the opening from the teat cistern to the outsideof the teat.

PHYSIOLOGY OF MILK SECRETION

Since little or no milk is secreted or synthesized during the milking process, all of the milk is present in the udder at the time of milking. Milk is formed or secreted by the cow in the interim between milking. In this interim, milk is synthesized in each functioning epithelial cell of the alveolus and is expelled into the lumen of the alveolus. Since all milk constituents and precursors are transported to the alveolus by the bloodstream, a great amount of blood must pass through the udder in the synthesis of milk. It has been estimated that from 300 to 500 lbs. of blood pass through the udder to synthesize 1 lbs. of milk.

Milk synthesis is most rapid immediately after milking, with the first synthesized milk filling the normal storage places in the udder. No increase in size of the udder or significant increase in mammary pressure occurs in the first hour after milking. The natural storage spaces of the udder hold about 40% of the milk present at milking time with the other 60% being accommodated through stretching of the udder. The udder increases about 1/3 in size during the interim between milking. With the filling of the natural storage spaces of the udder and the initiation of stretching, mammary pressure increases. With the increased pressure until equilibrium is reached, and, if milk is not removed and mammary pressure exceeds 40 mmHg (mercury), reabsorption of milk occurs.

So at the time of milking, the milk has been previously synthesized and stored in the udder. Forty percent of the milk is stored in the large duct system and cisterns and 60% of the milk is stored in the small duct systems and the alveoli.

MILK LETDOWN

Only a small quantity of the milk present in the udder is immediately available by natural drainage to the milker. This is the milk located in the cisterns of the udder. Most of the milk is stored in the small ducts and alveoli where natural drainage is prevented. Some mechanism is necessary, therefore, to force the milk into the large ducts and cisterns. This expulsion of milk from the alveoli and small ducts is termed *milk letdown* (Figure 13-2). Without milk letdown, only about 2 lbs. of milk per quarter could be obtained in milking.

Milk letdown is a nervous reflex produced by various stimuli. These include sucking of the teat by a calf, manipulation of the teats in washing or milking, auditory and visual stimuli, and other pleasant sensory stimuli regularly associated with milking. Such stimuli cause the release of the hormone *oxytocin* from the posterior lobe of the pituitary gland into the bloodstream. Oxytocin is produced by the hypothalamus and stored in the posterior pituitary. Oxytocin reaches the udder within a few seconds and causes contraction of the tissue of the alveoli and small ducts, forcing milk into the larger duct system. Following milk letdown. Mammary pressure increases more than 25% due to this expulsion mechanism. Since milk letdown lasts only 6 to 8 minutes, milking must be accomplished within this letdown period for maximum production.

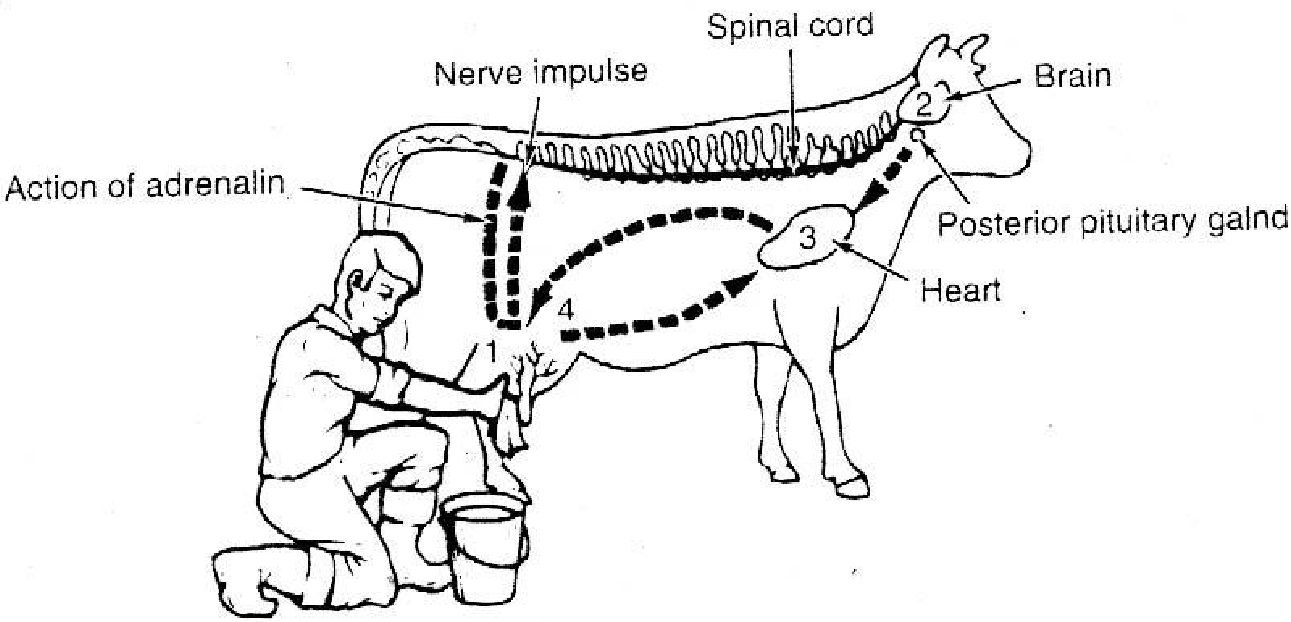


FIGURE2: Milk letdown is caused by various stimuli causing the cow to force milk from the storage places of the udder

Inhibition of Milk Letdown

When cows are frightened, angered, in pain, or ill treated, they will not let down their milk. This inhibition of milk letdown is caused by the release of *epinephrine* (adrenalin) from the adrenal gland. Epinephrine inhibition the action of oxytocin and lasts for 20 to 30 minutes.

Residual Milk

At a normal, thorough milking, not all of the milk is removed. Additional milk, termed *residual milk,* may be obtained after normal milking by an injection of oxytocin. The amount of residual milk is variable but is usually about 20% of the total milk produced.

THE MILKING PROCESS

Following milk letdown, milk is under pressure in the large ducts and cisterns but is prevented from draining through the streak canal by the sphincter muscle, which does not relax in milk letdown. In the milking process, some method must be used to force open the streak canal and allow milk to flow from the teat.

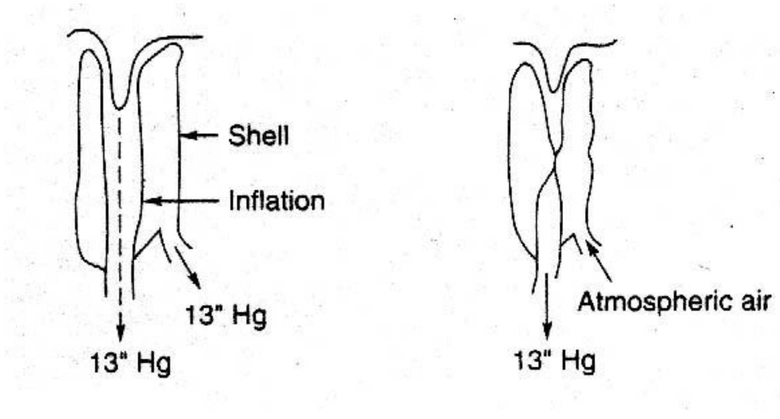
In hand milking, the opening between the gland cistern and the teat cistern is closed by squeezing the teat between the index finger and the thumb. Milk trapped in the teat cistern is then forced downward and through the streak canal by compressing the teat against the palm with the fingers.

Machine Milking

Unlike hand milking where the milk is forced the streak canal, machines use a vacuum or negative pressure to remove milk and to massage the teat. This is accomplished by the use of two vacuum systems: a continuous vacuum and an alternating vacuum.

These vacuum systems are utilized in a double-chambered teat cup assembly consisting of a teat cup shell forming the outer wall and a flexible inflation forming the inner wall. An airtight chamber is formed between the inflation and the teat cup shell. The inner chamber, or inside the inflation, supplies a constant negative pressure of 13 inches Hg to the teat end. (Normally, the vacuum gauge at the pump may read 15 inches Hg. However, this level decreases as the distance to the teat cup increases.). This constant negative pressure causes a pressure differential between the inside of the udder and the inside of the inflation or inner. The higher pressure in the teat forces the teat orifice open, and milk is allowed to flow through the streak canal. Thus milk is not squeezed or forced through the streak canal but is pulled or sucked from the teat by a constant negative pressure or vacuum.

Unless relieved, the constant vacuum will cause internal hemorrhaging and irritation to the teat tissue. An alternating vacuum and atmospheric air operates in the chamber between the inflation and the shell to alleviate this problem. When there is a negative pressure in the outer chamber, it counter-acts the continuous vacuum inside the inflation, and the inflation remains open. This is termed the *milking phase*. The vacuum inside the inflation draws the milk from the teat as described previously (Figure 3).



Milking phase **Resting phase**

FIGURE-3. Alternating vacuum and air between the shell and inflation creates the milking and resting stage of a milking machine.

When atmospheric air is allowed to enter the chamber. The vacuum inside the inflation causes it to collapse. This is termed the resting phage. The closed inflation relieves the teat of the constant vacuum, thus preventing congestion of blood and massaging the teat to maintain stimulation and proper milk letdown.

This vacuum and atmospheric air is alternated to the teat assembly by a pulsator, which changes the vacuum and atmospheric air through use of electrical current and a magnetic valve. The pulsation rate is the number of cycles of alternating vacuum and atmospheric air which occur per minute. This pulsation rate is 45 to 60 cycles per minute on most machines. The milking or pulsation ratio is the proportion of time spent under vacuum and atmospheric air and is usually approximately 60:40. this means that the inflation is open 60% (vacuum is on and in milking phage) and closed 40% (atmospheric air is present and is resting phage).

Milking Machine Parts and Terms

Following is a listing of milking machine parts and their functions:

1. *Milking machine*. The mechanical milking system and all auxiliary equipment.
2. *Vacuum pump*. Either a piston or rotary pump that produces the vacuum used in milking. Since the vacuum used is only a partial vacuum of 1/2 atmospheric pressure (13 in Hg), the function of the pump is to remove part of the air as it comes into the air inlets.
3. *Airflow meter*. The metering device that measures cubic feet per minute of air at a given vacuum level.
4. *Vacuum level*. The degree of vacuum in a milking system during operation, expressed as inches of mercury differential measured from atmospheric pressure and indicated by a conventional vacuum gauge.
5. *Vacuum tank*. A vessel or chamber in the vacuum system between the pump and the point of air admission that reduces and stabilizes pressure differentials.
6. *Vacuum controller or regulator*. An automatic air valve in the vacuum system that prevents the vacuum from exceeding a preset level by admitting atmospheric air as needed.
7. *Vacuum reserve.* The additional air-moving capacity of the vacuum pump after the requirements of the milking units, bleeder holes, operating accessories, and air leaks have been met – equal to the volume of air entering through the controller.
8. *Pulsator*. The mechanism that permits alternate vacuum / atmospheric pressure to exist between the rubber teat cup liner and the metal shell. This unit creates the massaging action.
9. *Claw.* The sanitary manifold that spaces and connects the four teat cup assemblies and the milk hose.
10. *Teat cup assembly.* Made cup of the shell, inflation, and air hose.
11. *Liner (inflation).* The rubber part of the milking machine in act ual contact with the cow's teat.
12. *Shell.* The cylindrical metal part of the teat cup.
13. *Milk cup.* A milk reservoir adjoining the claw between the milk tubes and the milk hose.
14. *Milk hose.* Connects buckets or pipeline to the claw.
15. *Receiving vessel or jar*. Receives milk from pipeline. Source of vacuum from the vacuum pump.
16. *Releaser*. Releases milk from under vacuum and discharge it to atmospheric pressure.
17. *Milk pump.* A high-speed pump which pumps milk from the releaser to the milk tank.
18. *Milk tank.* A refrigerated storage tank for "on the farm" storage of milk.

Figure 13-4 illustrates a typical milking parlor

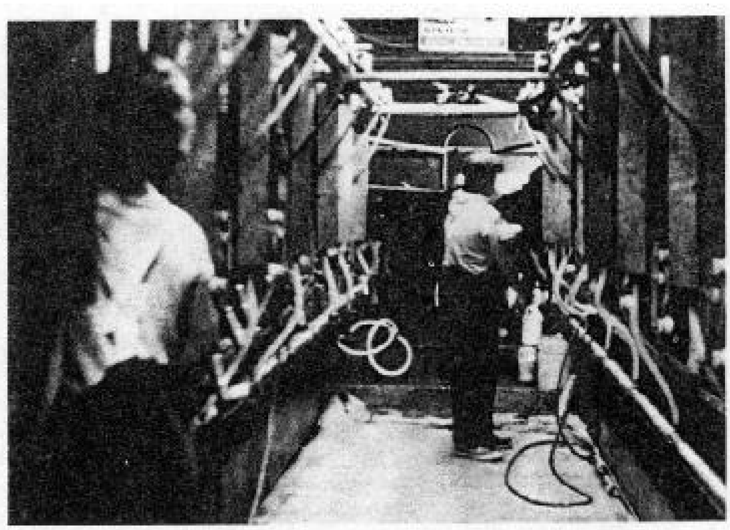


Figure 4. A modern herringbone-milking parlor is designed for the convenience of both the cow and the milker.

Suggested Milking Procedure

With the physiology of milk letdown and the mechanics pf milking machines in mind, the following milking procedures are recommended.

1. Massage and dry the udder and teats with an individual paper towel (not used on other cows) for cleanliness and proper stimulation. Strip two or three squirts of foremilk into a strip cup to check for abnormal milk (which would reveal the possibility of mastitis). In problem herds, pre-dip in a pre-dip sanitizer solution. The pre-dip should remain on the teat end for 30 seconds and then it should be wiped off. The teat must be completely dry.
2. Attach the milking machine promptly within 30 to 60 seconds after washing. This allows maximum use of the milk letdown reflex.
3. Return to the cow in 21/2 to 3 minutes.
4. Remove the teat cups as soon as each quarter is milked out. The milkers should be on the cow for about 5 minutes, depending on your production level and milking system.
5. Post-dip each teat in a sanitizer solution (teat -dip).
6. Sanitize the teat cups between cows.
7. Milk at regular hours, usually at 12-and 12-hours intervals or 10-and 14 hours intervals.
8. Provide feed to the cows immediately after they leave the milking barn to encourage them to stand for 15 to 20 minutes post-milking. This is especially effective at reducing coliform mastitis.

MASTITIS

Mastitis is an inflammation of the udder. It creates losses to the dairy industry stemming from decreased milk production and cost of medication, withholding milk from treated cows, and replacing animals culled from the herd because of infection and low production. Mastitis occurs in either clinical or sub clinical forms. Clinical forms represent about 25% of the cases and are characterized by fever, depression, weakness, loss of appetite, reduced milk production, abnormal milk, and possibly one or more swollen, hardened, or sensitive quarters of the udder. Abnormalities, such as clouding flakes, blood, or lumps, occur in the milk. Sub clinical mastitis represents 75% of the cases, but no signs of it are apparent without special testing. There is, however, a loss in milk production. Sub clinical cases can develop into clinical ones unless found and treated.

Microorganisms, especially streptococcus and staphylococcus, cause bacteria mastitis. Strep organisms that cause mastitis are transmitted from cow to cow. They are found in the udder of a cow with clinical or sub clinical mastitis and are transmitted to other cows if management practices are not followed to prevent spread of the bacteria. Antibiotic treatment is usually very effective in combating this type of mastitis. Staph organisms are found throughout the environment and usually enter the mammary gland through the teat canal (the opening at the end of the teat). Once in the mammary system, they invade healthy secreting tissues and cause the sub clinical form, a wasting away of the milk producing tissue of the cow. Treatment with antibiotics at the time of drying off (quit milking) is usually needed to combat this type of mastitis.

Mastitis prevention must include a mastitis testing and control program, milking machine maintenance, and care taken during the milking procedure by the person doing the milking. Sub clinical mastitis must be identified and controlled. This is done by routine CMT (California Mastitis Test) done at least once a month. The CMT test is simple, economical, and detects mastitis while still in the sub clinical stage. It can tell the dairy farmer about the status of the mastitis problem and indicate what steps need to be taken in preventing further spread. The CMT test causes white blood cells produced due to the infection to form a jell-like substance. The amount of jell and consistency is in direct proportion to the number of white cells in the milk. The reaction is scored as negative (no infection), trace, one two, or three (definite mastitis present).

DHI somatic cell count (SCC) taken once / month can reliably identify sub clinical cows. There is a strong relationship between SCC and milk yield. As which are sloughed off from the lining of the mammary gland during the natural loss of secretory cells. Most somatic cells are white blood cells, which move into the udder to fight off bacterial infections.

Although many of our nation's herds exceed SCC of 700,000/ml. Well managed herds can attain SCC of less than 100,000/ml. This substantial decrease in SCC can increase milk yield by more than 3200 ibs./305 day lactation/cow.

DHI program usually report SCC in linear scores (0~9). For each increase in linear score (for example, from 2 to 3) there is a doubling of the number somatic cells. The U.S.D.A. will soon be ranking sires based on their daughters' SCC (linear scores). There is a 25% heritability on linear scores.

Control of mastitis centers around keeping the disease from spreading and treating present infections. Anything that causes injury to the udder, such as improper milking procedures, improper functioning of milking machines, dragging the

udder through mud, and so on, or any contact the udder has with unsanitary conditions, will increase mastitis in the herd. Thus caution during the milking procedure, maintenance of the milking machine, and especially care on the part of the milker are important in mastitis control.

STUDY QUESTION

1. The correct term for a "cow's bag" or mammary system is an (?).
2. The mammary system is divided into (?) independent quarters.
3. Milk is actually secreted in grape-like structures called the (?).
4. Secreted milk is stored in the udder in the (?) of the alveoli, duct system, and the gland and (?) cisterns.
5. Milk is secreted from raw materials brought to the cells of the alveoli by the (?) cisterns.
6. The process of letting loose stored milk by the cow is termed (?)/
7. If the cow is frightened, angered, or ill treated (?) will not occur and very little milk can be harvested.
8. In milking, milk is removed from the udder by use of a (?) inside a milking machine inflation.
9. A regular, uniform milking procedure must be followed for maximum production. (True?, false) (?).
10. The disease (?) causes loss of the milk in most dairies and must be constantly combated by good management.

DISCUSSION QUESTION

1. Trace the secretion of milk, starting with the alveoli. Name and describe the function of each structure from the alveoli through the streak canal.
2. How is milk letdown and production influenced by the hypothalamus gland?
3. Compared to the old-fashioned form of hand milking, what precautions must be taken to prevent udder injures when using milking machines?
4. What causes mastitis? How can it be detected early? Give specific recommendations for treatment.
5. Outline steps to reduce SCC below 100,000 in a commercial dairy herd. Are these "extra" steps economically feasible for commercial dairy farmers?