

## SECTION I-1 NORMAL LACTATION

### 1. WHAT IS NORMAL?

To understand what is abnormal, we first need to understand how a healthy ewe produces milk.

#### 1.1 THE NORMAL ANATOMY OF THE MAMMARY GLAND

The mammary gland is composed of **glandular tissue**, which grows under the influence of hormones (see **Section I.1.2**). A diagram of the anatomy of the udder is provided in Fig. 1. This tissue produces milk, which is **secreted** into **alveoli** – small spaces shaped like balloons. There are millions of these alveoli in each mammary gland of a ewe. Milk produced in the alveoli travels into the ducts that connect the alveoli and eventually into the gland cistern and into the teat cistern.

Each alveolus is lined by secretory epithelial cells, which are responsible for secreting the various components of milk (**casein**, **lactose**, **lipids**, **minerals**, **vitamins** and water) (Fig. 2). The milk is actively forced out of the alveoli by the contraction of a layer of specialized cells (myoepithelial cells) which line the outside of each alveolus, and then through a series of ducts and into the gland cistern where it accumulates. This process is called “milk ejection”. The alveoli are also surrounded by a network of small blood vessels, which bring nutrients to the cells for making the milk, as well as bring disease-fighting white blood cells (somatic cells) and **antibodies**. The **lymphatics** travel along with the blood vessels, also providing a means for white blood cells to travel. The tissue between the alveoli (known as the **interstitium**) provides a frame for these blood and lymphatic vessels – as well as **nerves**. The glands are supported to the body wall by **suspensory ligaments**.

Apocrine secretion is the process whereby the milk is excreted by the secretory cells that line the alveoli (Fig. 3). The milk particles collect in the cell towards the end closest to the **lumen** of the alveoli and then are “pinched-off” the cell and into the alveolar lumen. The globules not only contain the components of milk but also small **cytoplasmic** particles. They are encapsulated in a thin membrane

Fig. 1.

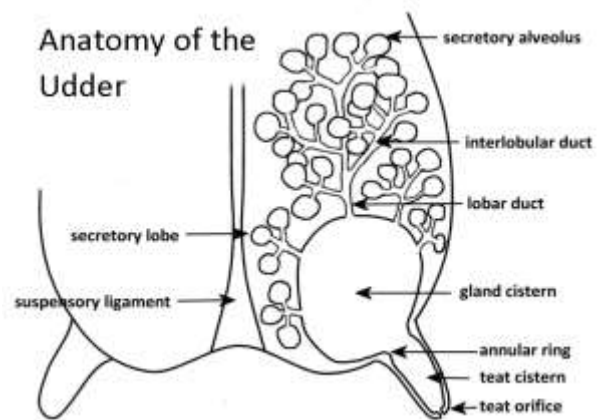


Fig. 2.

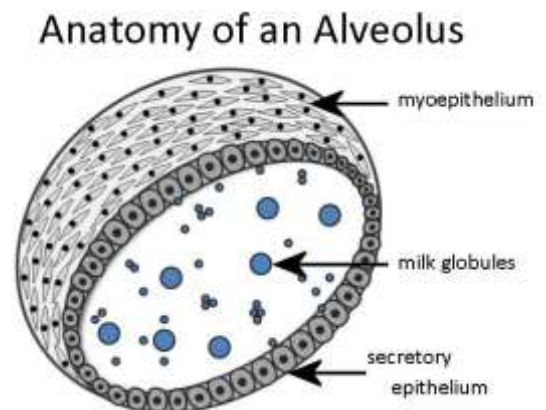
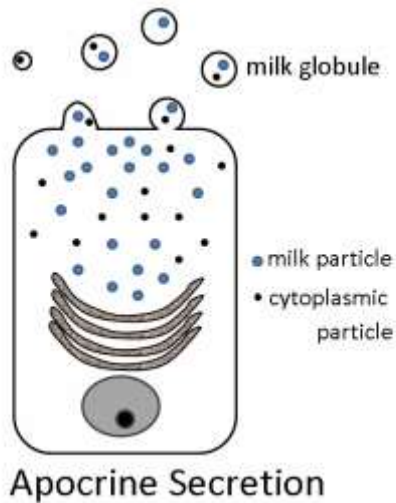


Fig. 4.



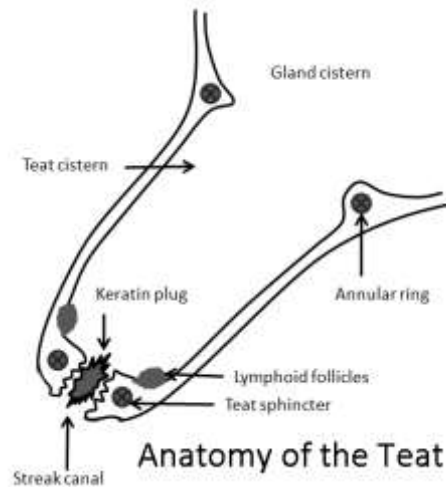
connects to the teat cistern. The suckling action of the lamb's tongue allows trapping of the milk from the gland cistern into the teat cistern and then squeezes it down the streak canal through the teat sphincter. The actions of a milker's hand or of the milking machine, mimics this.

The health of the teat is very important in preventing mastitis. The end of the teat is constructed to prevent introduction of bacteria. The teat sphincter normally closes after milking. However, it may take up to 2 h for the teat sphincter to close properly after machine milking, allowing bacteria to invade in the meantime. As well, just inside the teat cistern above the streak canal are accumulations of lymphoid cells (**lymphoid follicles**), which help to fight bacteria that may invade the teat. When the ewe is dried-off at the end of lactation, a **keratin plug** consisting of a waxy material secreted by the cells of the sphincter forms a physical barrier in the streak canal. Damage – acute or chronic, mild or severe – to the health of the teat is a major predisposing factor in mastitis.

that was part of the cellular structure. This is similar to goats but different from cows that produce milk by **merocrine** secretion. Because the cell is damaged slightly each time milk is excreted from it, factors of inflammation called **cytokines** are also released into the milk. This likely affects the normal level of somatic or inflammatory cells in the milk, as they are attracted to the presence of cytokines.

The teat is separated from the gland cistern by the annular ring at the top of the teat (Fig. 4). This ring contains many blood vessels and feeds the blood supply to the teat. The teat cistern is lined with a smooth **mucous membrane**. The teat **sphincter** is a strong muscle located at the bottom of the teat. The streak canal is located within the teat sphincter and

Fig. 3.



## 1.2 HOW IS MILK PRODUCED?

### 1.2.1 MAMMOGENESIS (MAMMARY GLAND DEVELOPMENT)

During pregnancy, the mammary gland structure develops. The number of blood vessels and milk secretory cells increase in preparation for lambing and milk production. New **lobules** of alveoli and the supporting ducts sprout as the mammary gland grows. This sprouting appears to continue for several weeks after lambing. The hormone **progesterone** is one of the main triggers for udder growth, in combination with the hormone **estrogen**. Progesterone is secreted by the ovary of the ewe (from the **corpus luteum** – a structure on the ovary which develops after the **ovum** or egg is **ovulated**), and after the first **trimester** of pregnancy – by the placenta of the developing **foetuses**.

### 1.2.2 LACTOGENESIS (PRODUCTION OF MILK)

This is the creation and secretion of milk, starting with **colostrum** prior to lambing and continuing through lactation. The number of secretory cells in the mammary gland determines the amount of milk produced. Damage from mastitis will greatly reduce milk production. Damage may be temporary or permanent. During lactation, estrogen is still important in directing milk production but progesterone is not.

#### GALACTOPOESIS

This term refers to the maintenance of lactation once lactation has been established. Lactation is maintained by the secretion of **galactopoietic** hormones and the removal of milk (milking). Hormones of importance include **growth hormone** (likely most important) and **prolactin**. Removal of milk removes a protein called feedback inhibitor of lactation (FIL), which inhibits milk production. This protein is important for drying-off (see below).

#### MILK EJECTION REFLEX (MILK LET-DOWN)

When the teats are stimulated with touch (which mimics nursing behaviour), the nerve impulses from the teats to the brain cause release of the hormone **oxytocin** from the **pituitary gland**, a very important gland that sits just below the brain inside the skull. Oxytocin travels through the bloodstream to the mammary gland and causes contraction of the myoepithelial cells that coat the outside of each alveolus. This causes the alveolus to contract and expels the milk from the lumen, forcing it down the ducts and into the gland cistern. This milk ejection occurs very quickly, within a few minutes of stimulation.

Milk ejection does not always require touch as the sight and sounds associated with the milking parlour may cause oxytocin release once the ewe has learned that the parlour is associated with milking. This is called a “**conditioned response**”. But proper stimulation is important to make sure that maximum milk-out occurs. If ewes are not properly prepped and the milking machine is put on without stimulation, milk-out time is longer and peak-milk flow rate is delayed. Without proper udder preparation the longer milking time damages the teat sphincter which may lead to invasion with mastitis-causing bacteria.

Stress, fear and pain will inhibit the action of oxytocin and therefore milk ejection. Release of the hormone **epinephrine** (produced by the **adrenal gland**) is part of this inhibition. **Cortisol**, another hormone produced by the adrenal gland in response to stress will also lower milk production. So it is very important to make sure that the milking procedure is as stress-free as possible to optimize milk ejection. This includes preventing loud noises or threats from other animals such as dogs or strangers.

#### RESIDUAL MILK

This term applies to the amount of milk left in the udder after milk ejection and milking. The volume tends to be less in young animals versus those that have had several lactations, but can be as much as 10 to 20% of total milk produced each day. **Machine stripping** will decrease this amount by about half but there are disadvantages to machine stripping with respect to udder health. Oxytocin injections before each milking may temporarily decrease the amount of residual milk but the ewe quickly becomes resistant to its effects.

### 1.2.3 INVOLUTION

When removal of milk ceases, the mammary gland will **involute**. However, even if the ewe continues to be milked, milk production will eventually decline and cease.

If milking ceases there is a build-up of FIL, which will reduce secretion of milk. Cells start to die (programmed cell death also called **apoptosis**) resulting in involution of the gland. This cellular debris is cleaned up by white blood cells (macrophages). Existing cells produce less milk. This state of active involution usually starts 24 to 48 h after milking stops.

The keratin plug forms in the streak canal of the teat, preventing bacteria from invading the udder. This usually happens within a few days of drying-off. The udder may enlarge but the milk is reabsorbed after a time. Milking off this secretion can be harmful to udder health as the keratin plug is removed thus allowing bacteria to enter.

Pregnancy will contribute to the decline in milk production, although ewes are often not bred until late in lactation (to lamb every 12 months, ewes would be bred at 210 days in milk), so it is unlikely to play a major role in lactation length.

### 1.2.4 THE DRY PERIOD

Ewes require a dry (non-lactating) period before they lamb again. Research in goats has shown that goats require at least 28 days or the next lactation milk production is lower. Cows require a minimum of 40 days. Without this quiet period, mammary cell proliferation is reduced at the next lambing and as much as 1/3 less milk is produced the following lactation. A ewe should have a dry period not shorter than 28 days and more appropriately a minimum of 60 days.

### 1.2.5 EFFECT OF SEASON AND DAY-LENGTH (PHOTOPERIOD) ON MILK PRODUCTION

Normally, sheep lactate during the spring and summer. However because milk is required year round for cheese production, there are financial pressures to have ewes' milk during all seasons.

Sheep milked when the **photoperiod** is long (i.e. spring and early summer), have a higher level of milk production than when milked when the photoperiod is short (i.e. late fall to early winter) or when the photoperiod is decreasing (e.g. in the fall). For this reason, there may be a financial benefit to expose ewes that lamb in the fall to long photoperiods using artificial light (e.g. 16 h of light per day). This could be combined with light programs that induce out of season breeding (See Section 1.2.5.5).

The length of photoperiod also seems to be important pre-lambing. Ewes exposed to short photoperiods (8 h of light each day) for 6 weeks pre-lambing have higher milk yields than ewes exposed to long photoperiods (16 h of light each day).

There is evidence that milk produced during the winter months has a higher cheese yield but this may be because those ewes have lower milk volumes at that time of year.

### 1.2.6 EFFECT OF MILKING FREQUENCY

If milk is not removed frequently from the gland the following will happen:

- There is increased pressure in the mammary gland which causes decreased blood flow and thus nutrients resulting in decreased milk secretion

- The hormone prolactin is not released
- The level of the FIL protein will increase and inhibit milk secretion

When nursing lambs, ewes are milked-out every one to two h. Traditional milking systems are usually every 12 h or twice/day. But milking is very labour intensive and if the interval could be decreased without loss of milk yield, there could be tremendous savings.

Between milkings, milk is stored not only in the alveoli but also in the gland cistern. Up to 75%, but usually around 50%, of total milk production can be stored in the cistern of the ewe as opposed to dairy cattle, which is generally around 20%. Sheep selected for larger gland cisterns tend to be affected less by decreased milking frequency, likely because they have more capacity for storage in the cistern.

There is evidence that after 90 days in milk (i.e. **mid-lactation**) it is possible to milk ewes as infrequently as every 16 h without loss of milk yield but not as infrequent as once/day. However, **early lactation** ewes should still be milked at least every 12 h, as it would decrease milk yield (20 to 60%), lactation length and persistency.

Milking 3 times per day is done with dairy cows to increase production. Studies in dairy sheep have shown an increase in milk yield of between 15 to 35% but there are few studies and conflicting results.

### 1.2.7 LACTATION CURVE

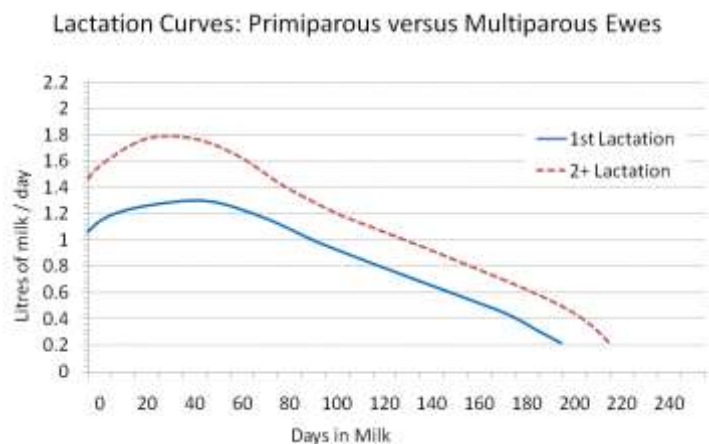
Total milk production of the ewe is dependent on the shape of the **lactation curve**, specifically time and height of peak milk (maximum daily milk yield in the lactation) and the persistency of the lactation (lactation length). More milk is obtained when the peak is high and the curve is flat and long.

Fig. 5 demonstrates the pattern of milk production if the ewe is milked starting one day post-lambing. As outlined below, there are many producers that start to milk the ewe later in lactation (approximately 30 days post-lambing). So, for those farms, persistency is critical to achieving economic returns on their animals.

Factors that affect peak milk and persistency include:

- Genetic selection for these traits
- Photoperiod (daylight length)
- Lambing season – affected by available nutrition
- Nutritional supplementation
- Number of lambs born
- Lactation number
- Stress and pain at the time of milking
- Number of times milked per day
- Presence of mastitis

Fig. 5.



Based on published studies, ewes that lamb in the spring tend to have higher peak milk, but ewes that lamb in the fall are more persistent. Ewes with multiple lambs tend to have higher milk production, perhaps as a consequence of higher levels of progesterone during pregnancy and so more alveoli. For those farms that wean at one month of age, the amount of milk suckled by the lamb(s) will have a great effect on the milk production once the ewe goes into the milking string. **Multiparous** ewes have



higher peak milk and more persistent production than first lactation ewes. First lactation ewes also have later peak milk, perhaps because the udder is slower to develop.

#### 1.2.8 NORMAL MILK PRODUCTION VALUES FOR DAIRY SHEEP

There is tremendous variability in milk production between breeds of dairy sheep, length of lactation and milking systems. Meat breeds tend to have very short lactations (< 90 days), dairy breeds are quite variable – up to 300 days, again depending on a number of factors covered above, including nursing period, but usually less than 240 days.

The more common dairy breeds in North America – East Friesian (Germany), Lacaune (France) and much less common, Assaf (East Friesian X Awassi (Israel))–have higher milk production values than meat breeds and their crossbreeds. Quoted ranges include: East Friesian – 300 to 600 kg (litres) over as much as 10 months of lactation with some as high as 900 kg; Lacaune – 270 kg over 5 ½ months; Awassi – 440 to 550 kg over 8 – 10 months. British Milk Sheep is a composite breed combining dairy breeds with some maternal trait meat breeds. Milk production values are quoted as 300 to 400 kg of milk over 6 - 7 months. Meat breeds tend to produce less than 70 kg of milk and often much less. Other Mediterranean breeds not currently present in North America, also have notable milk production values: Manchega (Spain); Chios (Greece); and many, many more. To help understand the comparisons between how milk production is reported: 1 L of milk weighs 1.030 kg; 1 kg of milk = 2.2 lbs; 1 pint of milk = 1.044 lbs.

Sheep milk is markedly different in composition than milk from cattle or goats. Fat is most often reported as a proportion of the milk produced although stage of lactation can vary this percentage quite a bit. Sheep have values from as low as 5% to a high of 9% but most often reported in the 6 to 7% range. This compares to 3.5 to 4.5% for dairy cattle and goats. Protein values are similar but slightly lower, most often reported as 4.5 to 6%. Lactose percentages tend to be similar to cattle and goats with most values falling between 4.5 to 5%. Proportion of milk as water tends to be less than cattle and goats, 83% versus ~ 88% - reflective of higher **total solids** (fat and protein).