3

Digestion of feeds in the milk-fed calf

This chapter describes the various processes of digestion in the milk-fed calf.

The main points in this chapter

- The adult animal requires a fully functioning rumen to digest the fibrous feeds. The rumen is undeveloped in newborn calves, which depend on abomasal digestion until weaned off milk.
- Milk bypasses the rumen via the oesophageal groove where it forms a clot and is digested in the abomasum.
- Rumen development depends on the intake of solid feeds, which stimulate the rumen wall to absorb feed nutrients.
- Rumination, or ‘chewing the cud’, is a good sign of rumen development in milk-fed calves.
- The inclusion of roughage in the diet allows for earlier weaning. However, calves must consume high energy/protein concentrates for growth as well as rumen development.

If all calves could be reared by their natural mothers, there would be little need for this book. Most beef cows do a good job of rearing their own offspring, provided due care is paid to their feeding and health. The first essential of good husbandry in rearing calves is to keep them alive and fit enough to perform well later on (Moran 2002). To do this, farmers need to understand the development of the calf’s digestive tract and the basic concepts of how calves digest their food. This is illustrated in Figure 3.1.

3.1 The calf digestive tract

An adult ruminant needs four functional stomachs to give it the ability to use the wide range of fibrous feeds available.

The reticulum and the rumen harbour millions of microbes, which ferment and digest plant material. The omasum allows for absorption of water from the gut contents. The abomasum or fourth stomach is the true stomach, comparable with that in humans and allows for acid digestion of feeds.

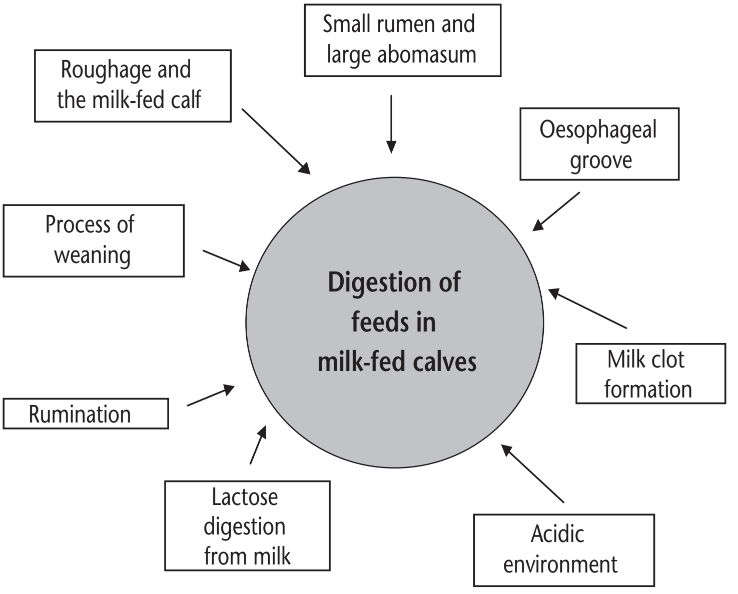


Figure 3.1. The key factors involved in digestion of feed in milk-fed calves

The very young calf has not developed the capacity to digest fibre and so the abomasum is the only functional stomach at birth. Both newborn and adult animals have a functioning small intestine, which allows for the alkaline digestion of feeds.

Figure 3.2 illustrates the anatomy of the stomachs and small intestine of a newborn calf. This schematic diagram shows the relative sizes of the four stomachs, the oesophageal groove, which runs from the oesophagus through the rumen to the abomasum, and the pyloric sphincter or valve at the bottom of the abomasum, which controls the rate of movement of gut contents into the duodenum.

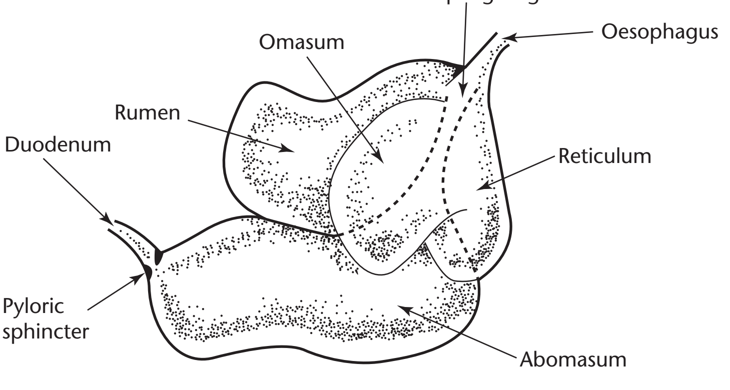


Figure 3.2. The four stomachs and duodenum of the newborn calf

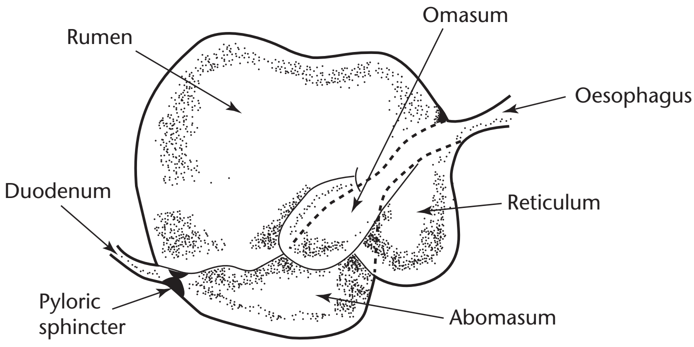


Figure 3.3. The four stomachs and duodenum of an adult cow

The omasum and abomasum account for about 70% of the total stomach capacity in the newborn calf. By contrast, in the adult cow, they only make up 30% of the total stomach capacity (Figure 3.3).

Digestion of feeds is aided by the secretion of certain chemicals called enzymes into the various parts of the gut. For example, calves produce the enzyme rennin in the abomasal wall to help digestion of milk proteins, while lactase is produced in the wall of the duodenum for digestion of milk sugar (lactose). These enzymes operate most effectively at different levels of acidity in the gut contents: acid in the abomasum and alkaline in the duodenum. To achieve this, the calf secretes electrolytes, or mineral salts, with the enzymes, to change the gut contents from one type to another.

The end products of digestion of the different components of feeds are absorbed through the gut wall into the bloodstream where they are taken to the different parts of the body for the animal's growth and development.

3.2 The milk-fed calf

Milk or calf milk replacer, whether sucked from a teat, or drunk from a bucket, is channelled from the oesophagus via the oesophageal groove into the abomasum. This groove is a small channel in the rumen wall that is controlled by muscles that allow liquids to bypass the rumen.

The groove is activated in response to different stimuli. It works well when calves suckle from their mothers or from teats, but sometimes does not work when they drink from a bucket. This appears to be a psychological condition in response to calves being separated from their mothers. Most calves can be trained by patient coaxing to drink quickly and well, responding to the new daily routine and the substitute mother in the shape of the calf rearer. When milk or milk replacer enters the abomasum, it forms a firm clot within a few minutes under the influence of the enzymes rennin and pepsin. This is the same process involved in making cheese or junket, using rennin to coagulate the milk protein. The clotting of milk slows down the rate at which it flows out of the abomasum, thus allowing for a steady release of feed nutrients throughout the gut and eventually into the bloodstream. It can take as long as 12–18 hr for the milk curd to be fully digested.

The enzymes acting on milk proteins require an acidic environment and this is provided by hydrochloric acid secretion into the abomasum. However, until the acid digestion is operating efficiently, which can take up to 7 days from birth, the only form of protein that can be digested is casein. There is no substitute for casein in the very young calf. Milk replacers containing other forms of protein cannot be digested until the calves are older.

Digestion of milk can be improved by including rennet, which can be obtained from cheese factories, or commercial calf milk additives for the first week or so. These can provide additional acids to reduce abomasal pH, and enzymes and specific bacteria to increase the rate of breakdown of the milk curd. Such additives are called probiotics, in that they aid in normal digestive processes. Research has not always found these to improve calf performance and health greatly, although they are more likely to be beneficial when calves are suffering from ill health.

Any milk from a previous feed is enveloped in this newly formed clot. Liquid whey protein and lactose are rapidly separated from the milk curd and pass into the abomasum. The milk fat embedded in the milk curd is broken down by another enzyme, lipase. This is secreted in the mouth in saliva and incorporated when milk is swallowed. Teat feeding, rather than bucket feeding, seems to produce more saliva and hence more lipase. Further digestion of the milk protein and fat occurs in the duodenum with the aid of enzymes produced in the pancreas.

Lactose, which is quickly released from the milk curd in the abomasum, is broken down to glucose and galactose and these are absorbed into the bloodstream to form the major energy sources for young calves.

Fats are broken down into fatty acids and glycerol for absorption and use as energy, while proteins are broken down into amino acids and peptides for absorption and use as sources of body protein.

Starch, such as from cereal grains, is an important source of energy in older calves, but calves in their first few weeks of life cannot digest starch.

The abomasum is not acidic until the calf is 1–2 days old and this has advantages and disadvantages. The major advantage is that the immune proteins in colostrum cannot be digested in the abomasum, so are absorbed into the bloodstream in the same form as when produced by the cow. This ensures their role as antibodies to protect against infection. The low acidity of the abomasal contents in the newborn calf constitutes a potential risk from the bacteria (and probably viruses) taken through the mouth. These will not be killed by acid digestion and they can pass into the intestines where they can do the most harm. All calves pick up bacteria in the first few days of life and this is essential for normal rumen development. However, some of the first bacteria to colonise the gut can also cause scouring. Provided the calf has drunk colostrum, the maternal antibodies can control the spread of these more harmful bacteria.

The milk-fed calf must then produce an acid digestion in the abomasum and an alkaline digestion in the duodenum. This is achieved by the production of electrolytes in the gut wall.

Calves suffering from scours due to nutritional disturbances or bacterial infections can lose large amounts of water and electrolytes in their faeces. These must be replenished as part of the treatment for scours.

Colostrum is the first milk produced by newly calved cows. Not only does it provide essential feed nutrients, it supplies maternal antibodies that allow passive transfer of immunity against diseases of calves. Recommendations for colostrum feeding are discussed in Chapter 5.

3.3 Rumen development and the process of weaning

After calves are weaned, the cost of rearing declines markedly. Feed costs are lower, labour inputs are reduced and incidence of ill health is less. It makes economic sense to wean calves as soon as is reasonable. However, the calf is forced to undergo several dramatic changes, namely:

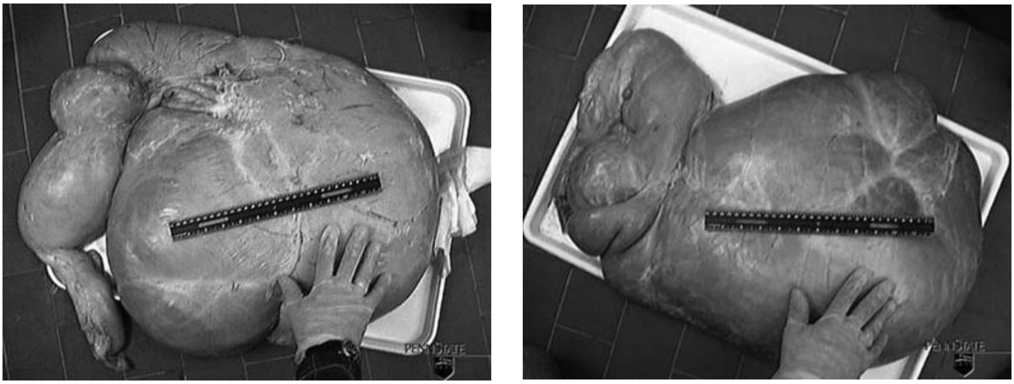
- The primary source of nutrients changes from liquid to solid.
- The amount of dry feed the calf receives is increased.
- The calf must adapt from a monogastric to a ruminant type of digestion, which includes fermentation of fibrous feeds.
- Changes in housing and management often occur around weaning, which can add to stress.

At birth, the rumen is a small and sterile part of the gut, but by weaning it must become the most important compartment of the four stomachs. It must increase in size, internal metabolic activity and external blood flow. The five requirements for ruminal development are:

- the establishment of bacteria
- plenty of liquids
- the outflow of material (muscular action)
- the absorptive ability of the tissue
- a substrate to allow bacterial growth, such as recycled minerals, as well as feed nutrients.

Prior to consumption of solid feeds, bacteria exist by fermenting ingested hair, bedding and milk that flows from the abomasum to the rumen. Most water entering the rumen comes from free water (actual water, not water contained in milk or milk replacer solution). Milk will bypass the rumen via the oesophageal groove, whereas free water will not.

The rumen develops from a very small organ in newborn calves (1–2 L) into the most important part of the gut (25–30 L) by 3 months of age. It can enlarge very quickly during the first few weeks of life, given the right feeding management. Rumen growth only occurs under the influence of the end products of rumen digestion, which result from the fermentation of solid feeds by the rumen microbes. Development largely occurs through growth of rumen papillae on the rumen wall (leaf-like structures on the internal surface), which increase the surface area of the rumen and hence its ability to absorb these end products of digestion.



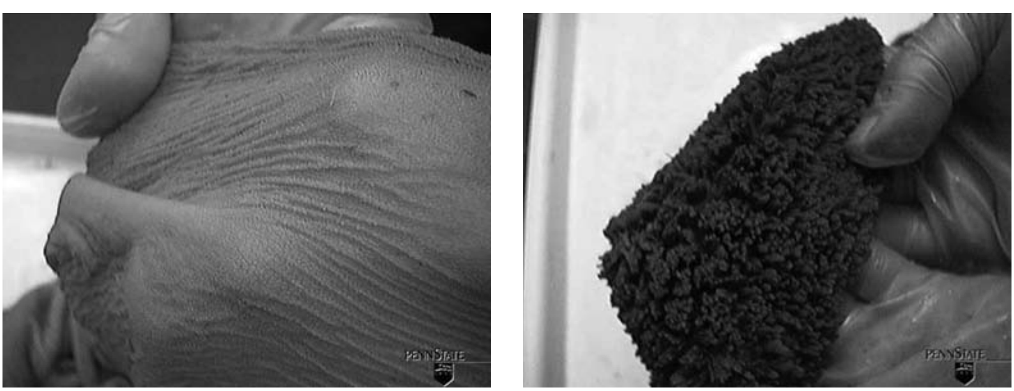
The dissected rumen of a 12-week-old calf fed entirely on milk and hay (left) or on a combination of milk, hay and grain (right). Note the difference in rumen capacity as a result of grain feeding. (Photos used with permission.)

The dramatic effects of feeding cereal grain, in addition to milk and hay, are visually depicted in changes in rumen size and rumen wall development of a 12-week-old calf in the photos below.

The rumen's capacity and the intake of solid feed are closely related. Rumen development is very slow in calves fed large quantities of milk. The milk satisfies their appetites so they will not be sufficiently hungry to eat any solid feed.

Rumination, sometimes called 'chewing the cud', can occur at about 2 weeks of age and is a good indication that the rumen is developing. Solid feeds and rumination both stimulate saliva production and this supplies chemicals such as urea and sodium bicarbonate to produce the substrates for bacterial growth.

When weaning calves early, it is important to limit both the quantity of milk offered and its availability throughout the day. It is also essential to provide solid feeds. Roughages (of low or high quality) should be offered in combination with high-quality concentrates. Roughages stimulate rumen development, while concentrates supply feed



The rumen wall of a 12-week-old calf fed entirely on milk and hay (left) or on a combination of milk, hay and grain (right). Note the difference in papillae development as a result of feeding grain. (Photos used with permission.)

nutrients not provided by the limited quantities of milk offered. Without the concentrates, calf growth is slow but the rumen still develops, resulting in undesirable pot-bellied animals.

Urea supplies nitrogen for the microbes, while sodium bicarbonate acts as a rumen buffer, helping to maintain a steady pH in the rumen contents. This is particularly important when calves eat large quantities of cereal grains later in life because the rumen microbes can produce a lot of lactic acid during fermentation.

Grain poisoning or acidosis occurs when lactic acid levels are excessively high and become toxic to the rumen microbes and eventually to the animal. As well as the end products that are absorbed through the rumen wall, microbial fermentation produces the gases carbon dioxide and methane, and these are normally exhaled. When something prevents the escape of these gases from the rumen, bloat can result at any stage of life.

3.4 The role of roughage in the weaning process

The inclusion of roughage in the diet improves intakes, performance and allows for earlier weaning.

Fresh pasture is not the ideal roughage source for milk-fed calves because it has too little fibre and a low feed energy density. Its high water content limits its ability to provide adequate feed energy for the rapidly growing animals. Until their rumen capacity is larger, young calves just cannot eat enough pasture for good growth, unless it is very high in quality.

Calves reared on restricted milk plus concentrates display good rumen function by 3 weeks of age and have sufficient rumen capacity for weaning by 4–6 weeks of age. However, if the diet was restricted milk plus high-quality pasture, rumen capacity may not be sufficient for weaning until 8–10 weeks of age. Even then, growth rates would be lower in calves weaned onto pasture alone because of insufficient energy intake due to the physical limitations of rumen capacity.

If too high in quality and fed *ad lib* (that is fed to appetite), calves seem to prefer the roughage to concentrates, leading to a reduced intake of feed nutrients and slower growth. When clean cereal straw and concentrates are both fed *ad lib* together with limited milk, calves will eat about 10% straw and 90% concentrates. Without the roughage and the resulting rumination, rumen development will be slower due to insufficient saliva and end products of fibre digestion.

This chapter highlights the importance of encouraging early rumen development through feeding management to reduce total feed costs and allow the calf to move from the milk-fed calf phase to the weaned heifer phase, when it becomes less dependent on the rearer for feed, disease and general herd management.

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