The Digestive System

In order to make use of the nutrients stored in feedstuffs, all animals must first break down (digest) feed into a form that can be absorbed by the body. The focus of this chapter is to provide a basic overview of the structures, abilities, and limitations of the sheep's digestive system. Sheep belong to a group of herbivores called ruminants. Ruminants are able to digest a large portion of the nutrients contained in fibrous plant material due to their unique digestive system, which integrates a large microbial population with the animal's own system. Although this system is remarkably efficient, proper feeding management is needed to maintain healthy and productive animals. Mismanagement of a ruminant's diet can be disastrous.

Structures of the Digestive System:

The digestive tract is composed of the mouth, esophagus, stomach, small and large intestines, and anus. Various other structures and organs, such as the salivary glands and liver, also aid in digestion. A few of the key structures are described below:

***Salivary glands*:** There are three sets of glands that drain saliva into the mouth. The saliva mixes with the feed that is being chewed and is swallowed with the feed. Saliva, which has a high pH, is very important in maintaining the correct pH balance in the rumen and is a key component of rumen fluid. Therefore, the salivary glands in ruminants are extremely productive. An adult sheep, for example, may secrete over 25 litres of saliva per day.

***Esophagus**:* The esophagus is a long muscular tube that runs to the stomach. When feed is swallowed, muscles in the esophagus move the food to the rest of the system

Stomach

The stomach of ruminants greatly differs in structure and function compared to monogastrics (dogs, pigs, horses, humans etc.). Monogastrics have a relatively simple, single-chambered stomach. Sheep, like other ruminants, have three additional chambers (reticulum, rumen, and omasum) that feed passes through before reaching the 'true' stomach (abomasum).

Reticulum: The reticulum is a blind pouch of the rumen that acts as a holding area for feed after it passes down the esophagus. The reticulum receives material coming into the digestive system and will trap large inedible objects. As there is no distinct division between the rumen and the reticulum, they are often referred to together (reticulo-rumen).

Rumen: The rumen is a very large muscular pouch, which extends within the left side of the body cavity from the diaphragm to the pelvis. The rumen is a critical site for feed digestion in ruminants. The rumen has a complex environment composed of microbes, feed at various stages of digestion, gases, and rumen fluid. The microbes (bacteria, protozoa and fungi) number in the billions and are the basis of the fermentation (digestion) process. The rumen contents separate into three zones based on their density and particle size: gas (fermentation by-product) rises to the top; small, dense particles sink to the bottom (grain, well digested forage), and lighter, longer particles form a middle layer on top of the rumen fluid (recently eaten forage). Feed remains in the rumen until the particles are small enough to pass into the omasum.

Approximately 70% of the energy requirements of the animal are supplied through microbial activity in the rumen. As proteins vary in how easily they can be dissolved within the rumen fluid, the amount supplied through the rumen depends on the type of protein being provided in the diet. Some types of proteins will be completely dissolved and utilized by the microbes, while other types pass from the rumen intact (by-pass proteins).

Omasum: The omasum is much smaller than the rumen. It grinds feed particles (digesta) coming from the rumen/reticulum to reduce the particle size and to absorb excess moisture. As fermentation requires large amounts of fluid, it is important to recapture water to avoid dehydration. From the omasum, digesta proceeds into the abomasum.

Abomasum: The abomasum is called the 'true' stomach. It functions in a similar manner as the stomach of a monogastric, including the production of acids to aid in digestion of certain feed components. Protein that is insoluble in the rumen fluid, a small percentage of starch, and any fats in the diet are passed from the rumen into the abomasum relatively intact. As large numbers of microbes are also flushed from the rumen, the abomasum is specialized to break down the microbes. These microbes are an important source of nutrients for the ruminant.

Small intestine

The small intestine is the main site of absorption of nutrients that have by-passed the rumen. The small intestine is approximately 85 feet long in adult sheep. Bile and pancreatic juice drain into the small intestine to aid in digestion of certain feed components, such as dietary fat.

Liver

The liver is a large organ, about 1.5% of an animal's live weight. It is located towards the front of the animal's body cavity, just behind the diaphragm. Newly digested and absorbed nutrients are transported from the absorption sites to the liver for storage and/or further processing. The liver also produces bile that drains into the intestine to aid in the digestion of fats.

Large intestine

The mammalian large intestine consists of the caecum and the colon. The caecum is a blind pouch that opens into the digestive tract. In ruminants, approximately 10-15% of the animal's energy requirement is supplied through microbes in the caecum.

The Digestive System in Lambs

When lambs drink milk, the rumen and reticulum are generally by-passed. Suckling causes a reflex action bringing the walls of the reticulum together to form an esophageal groove leading directly to the omasum. This reflex is very important in newborn lambs, to ensure that antibodies in the colostrum are transported intact to the abomasum. The esophageal groove generally does not form when lambs are fed milk by a stomach tube. Without the reflex, the milk will end up in the reticulum and may cause bloating, as the milk will be poorly digested.

During the first few weeks of a lamb's life, the rumen is very small and has no microbes. The rumen will become functional as the lamb begins to consume more plant material and the rumen is 'seeded' with microbes.

Rumen Function:

Rumen microbes

Everything that the sheep eats is subjected to microbial digestion. The feed you see your sheep consume is actually, for the most part, being used to feed and maintain the rumen microbes. The microbes in turn provide nutrients to the sheep. Like any other organism, the microbes need to be fed. If an animal is held off feed for a few days, the microbial population will die. If this occurs the ruminant will be unable to utilize feed until microbes are reintroduced to the rumen.

Microbes secrete enzymes directly onto the feed particles and into the rumen fluid. Therefore, feed is broken down directly by the microbes and also by the surrounding fluid. Unlike many mammalian groups that rely on both carbohydrates and fats, the vast majority of energy in ruminant diets is supplied through plant carbohydrates. Plant carbohydrates are classified as either insoluble or soluble, based on how easily they can be digested. The rigid, fibrous plant cell wall is largely comprised of insoluble carbohydrates (mainly cellulose), while the inside of the cell contains more soluble forms (starch, hemicellulose etc.). The cell walls of different types of plant material and plants at different stages of development will vary in thickness and therefore contain different proportions of soluble and insoluble carbohydrates. Much of the nutritive value of plants with thick cell walls (forages) is unavailable to mammals without microbes to break down the cellulose. Feeds high in starch (e.g. grains) provide more readily available energy than feeds high in cellulose (e.g. forages).

As microbes are breaking down and utilizing carbohydrates in the rumen, they produce energy rich by-products called volatile fatty acids (VFA's). It is the VFA's rather than the original plant material that provide energy to the ruminant. The VFA's are absorbed by the animal through the rumen wall, after which they are carried through the blood system to the liver for further processing and storage. There are many types of microbes in the rumen. Although their functions vary and even overlap in some cases, they can be classified into two general groups based on the type of carbohydrate that they digest. One group is adapted to breaking down the fibrous cell wall (cellulose), while the other group digests soluble particles (starch). Therefore, the composition of the microbe population (cellulose digesters vs starch digesters) will vary depending on the type of feed provided to the sheep.

Rumen pH

The normal environment of the rumen is neutral (pH of 6 to 7) and most rumen microbes can only thrive in this type of environment. Therefore, the acidic by-products of fermentation must be removed from the rumen continuously by absorption through the rumen wall and saliva (high pH) must be added to the rumen fluid frequently to maintain the proper pH. Many of the digestive problems in ruminants occur when the mechanisms regulating the pH balance are disrupted and the rumen becomes too acidic (acidosis). As discussed below, the diet and the microbe population have a direct influence on the rumen pH. Increased fermentation rates can lead to a rapid decline in rumen pH. The speed of digestion is dependent on the type of feed and the particle size.

Type of feed and changes in diet

Ruminants can adapt to diets with different levels of forages and grains. However, sudden changes from forage to easily digestible feed can cause a major disruption in the microbe population of the rumen. For instance, the rumen microbe population of an animal fed only grass hay will be largely comprised of cellulose-digesting microbes. If the diet is suddenly switched to a high grain, low forage ration, it will take time for the population of MOST starch-digesting microbes to increase. This creates a favourable environment for a population explosion of o ne particular type of starch-digesting microbe. This microbe produces large levels of lactic acid. Although a small amount of lactic acid is a normal by-product of fermentation, very large levels will cause the rumen pH to drop below 5. This will kill the cellulose-digesting microbes, and prevent the growth of other types of starch-digesting microbes. As the lactic acid microbes are able to survive in a low pH environment, their population will continue to increase, further adding to the drop in pH. This is a very serious situation for a ruminant. At the very least, rumen function and feed utilization will be slowed, and the rumen will need to be re-populated with essential microbes. In severe cases, the animal could die, due to bloat or lactic acidosis. It is very important, therefore, to make changes to high-energy diets slowly. If grain is increased incrementally over a few weeks the transition in the microbe population will occur gradually, preventing an overpopulation of the lactic acid producing microbes. Even with animals adapted to high-energy diets, precautions should be taken to prevent disruptions in microbe populations

(i.e. maintain a regular feeding schedule and prevent animals from ingesting very large amounts of easily digestible feeds at one time)

Particle size: Very small feed particles can be quickly surrounded and digested by microbes, increasing the fermentation rate. One way to moderate the digestion of small particles, such as grain, is to provide the animal with sufficient fibre. As mentioned earlier, the long fibres of recently consumed forages settle in the middle region of the rumen, where they form a structure known as a rumen mat. When a mat is present, it will entangle small particles (e.g. grain, alfalfa leaves), which helps limit their exposure to microbes and slows their digestion. It is important to note that in the case of very fibrous feeds (straw), particle size may need to be decreased. This type of feed may be chopped to reduce the particle size to help increase intake and digestion.

Rumen Gases*:*

Large quantities of gas are produced within the rumen as a by-product of fermentation. (~5 litres per hour in a sheep). Ruminants need to frequently rid themselves of these gases, mainly through eructation (belching). Bloating occurs if the animal is unable to release gas or if gas is produced faster than it can be released. If bloating is severe, the rumen enlarges to the point that it pushes against the lungs, potentially suffocating the animal. The rate of gas production is dependent on the speed of fermentation, which (as noted above) varies with the type of feed and the particle size. Rumen pH is also a factor for gas release as it affects rumen motility (see below). There are two types of bloat:

- **Frothy bloat** occurs when the gas becomes trapped within the rumen fluid creating a frothy layer. As the gas is not in a 'free' form, it cannot escape the rumen. This type of bloat most frequently occurs when animals are fed high protein forages (legumes) that have a small particle size (e.g. alfalfa with a high percentage of leaves or finely chopped forage). Precautions should be taken when switching sheep to legume hay, and particularly, when first turning sheep into pastures with a high legume content.
- With **free gas bloat**, the gas forms a distinct layer, but the animal is unable to release it because of decreased rumen motility (see below).

Rumen Motility

Approximately every half-minute, the rumen and reticulum are subjected to strong muscular contractions which cause churning and mixing of the rumen contents. The highest frequency of contractions occurs during feeding. The rumen environment significantly affects motility, and motility will slow down or cease (rumen stasis) if rumen contents become overly acidic. Consequently, the type of diet will influence rumen motility, with high-fibre diets increasing motility relative to low fibre diets.

Rumen motility aids rumen function by:

a. Increasing efficiency of digestion: Churning of the rumen contents helps increase the exposure of feed particles to microbes.

b. Release of gas: As mentioned earlier, the gas produced during fermentation remains in the top portion of the rumen. As the rumen contents are moved by muscles contractions, the gas bubble is shifted to the esophageal opening, allowing for eructation. If the contractions are decreased by a low pH, gas release will be decreased and the animal may bloat (free-gas bloat).

c. Ruminating or 'chewing cud': Rumen churning also stimulates cud chewing. The passage to the omasum is narrow which limits the size of the particles that can be passed into the rest of the digestive system. While feeding, ruminants take fairly large bites and swallow the material with little chewing. Therefore, sheep must continue to physically break down the feed after it has been swallowed the first time. At regular intervals boluses of feed (cud) being held in the reticulum are brought back up to the sheep's mouth to be further chewed and then swallowed again. This process (rumination) reduces the size of the forage particles and greatly increases the surface area available for microbial digestion. Rumination also increases rumen pH by stimulating the release of saliva.

d. Digesta movement to the omasum: Rumen contractions help move digested rumen contents into the omasum. Impaction of the rumen may result if motility is suppressed for a significant length of time.

Summary: Feeding for a Healthy Rumen

- **Feed sufficient fibre:** Ruminants are designed to consume and digest forage, and producers will generally have few problems if a high percentage of the diet consists of grass forages (~1.5% body weight). Although high grain rations can be successfully fed, animals receiving this type of diet must be managed carefully to avoid digestive disturbances. Providing forages together with grains helps to ensure that the high-energy feeds are not digested too quickly, by producing a rumen mat. A diet high in forages also aids in maintaining the rumen pH by increasing rumen motility and encouraging rumination.

- **Feed at regular intervals:** This will help maintain continuous fermentation and prevent acidosis by maintaining a consistent population of bacteria (i.e. no sudden die-offs or explosions in microbe numbers).

- **Make ration changes gradually:** Ration changes should be made over a two-week period to allow the rumen microbes time to adjust. This is particularly important when switching from a low energy diet to high energy feed (i.e. going from a grass forage diet to either a high grain or high alfalfa diet). Making ration changes too quickly can lead to digestive disorders such acidosis and bloat.

- **Take precautions with high-energy diets or feeds with fine particle size:** Even if an animal is adapted to a high-energy diet, a sudden intake of grain may cause digestive disturbance through a rapid decrease the rumen pH (acidosis), causing rumen stasis.

- **Feed forage before grain or provide free choice forage:** This helps ensure the formation of a rumen mat to slow the fermentation rate of grain and maintain rumen pH.

- **Do not severely limit energy:** Although most of the recommendations above deal with providing too much energy, only feeding very low energy, fibrous feeds (e.g. straw alone) may also cause problems. As the opening from the rumen/reticulum to the rest of the digestive system is small, feed particles must be small to pass through, and make space in the rumen for new feed. With very fibrous feeds, the rate of passage is too slow to meet the energy requirements of the animal. Although there may be lots of feed available, the animal will be limited by the capacity of the rumen. Very fibrous feed may also lead to rumen impaction, if the feed is unable to pass to the omasum.