New Entrants to Farming

Ruminant Nutrition and Forage analysis

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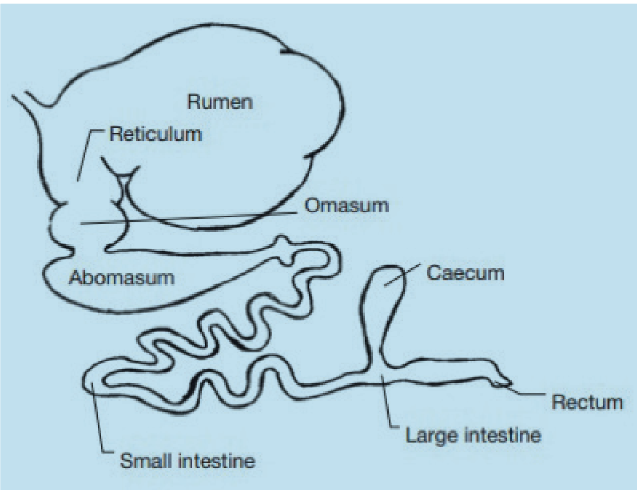
Overview of the Rumen

In order to get the best performance from ruminants it is helpful to know the primary functions of their specialised digestive system. Firstly, there are many different species of ruminant animals including cattle, sheep, goats, deer and buffalo. Ruminants can digest forages and fibrous roughages that monogastric's (e.g. humans, pigs and poultry) can't. Ruminants have evolved a special system of digestion that involves microbial fermentation of food before it is then exposed to their own digestive enzymes. Instead of one compartment to the stomach, a ruminant has four. As shown in figure 1 these are the reticulum, rumen, omasum and abomasum. The rumen being by far the largest section in the digestive tract.

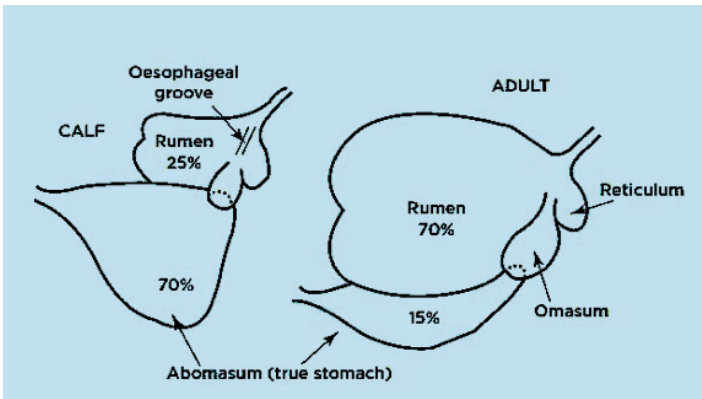
Figure 1:



Development

Newly born animals are classed as 'pre-ruminants'. Although they have the same four stomach compartments as the adult, the rumen is significantly smaller. Figure 2 shows that the largest part of the digestive tract is the abomasum (also known as the true stomach which most resembles how a humans stomach functions). At this point the pre-ruminant calf or lamb digests feed the same way as a young monogastric animal. The animal is dependent on milk or milk replacer as a source of carbohydrates and protein.

Figure 2:



Source: Teagasc development of the calf digestive system

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The action of suckling causes the milk to be channelled through a tube-like fold of tissue known as the oesophageal groove, shown in figure 2. The milk bypasses the rumen therefore avoiding being fermented and goes straight to the abomasum. As the calf or lamb begins to eat solid food, the reticulum and the rumen begin to develop and increase in size until in the adult they comprise 85% of the total capacity of the stomach.

Figure 3:

Milk Only Diet **Milk and Grain Diet** **Milk and Hay Diet**

Figure 3 shows the comparison of the rumen lining of 6 weeks old calves fed 3 different diets. The milk only diet has a smooth surface and is white in colour showing no blood circulation. The milk and grain, here you can see papillae have developed the wall is much thicker and darker in colour allowing for significant feed absorption. In the milk and hay diet, the papillae are not developed at all and the rumen wall hasn't thickened. (Source: Penn state University)

A key part of rumen development is the proliferation and growth of the rumen lining known as the epithelium. Figure 3 shows the effect different feed has on this lining. Papillae are finger like projections that helps increase the rumens surface area for feed absorption. At birth the rumen papillae are short and inactive. As the rumen develops the papillae increase in length and thickness. As you can see in figure 3, grain stimulates rumen development more than feeding hay. The reason for this is the type of volatile fatty acids (VFA's) produced when hay is digested. Hay mostly produces acetic acid which the rumen walls don't use for papillae development, where as grain digestion produces butyric and propionic acids that causes the papillae to grow. Therefore providing fibre in the diet can increase the size of the rumen but it does not cause the rumen lining to develop.

Practical Tip: It's important to make gradual changes to any ration to allow the rumen to adjust. Ideally making changes slowly over a 2 week period particularly if transitioning from a forage based ration to a concentrate based one.

The time it takes for them to change from using the abomasum to efficiently using all four stomachs depends on the type of food it is on. For example if milk is freely available for a long period, they will have a low appetite for other feeds and rumen development will be slower. On the other hand if feed management encourages the calf/lamb to eat solid feeds, such as introducing creep feed or bucket reared calves who are introduced to concentrate at a week old, rumen development is enhanced and they reduce their reliance on milk.

Rumen Microbiome

The rumen contains a large array of micro-organisms and it is their job to transform carbohydrates, protein and other fermentable substances into volatile fatty acids (VFA's), ammonia, methane, carbon dioxide and microbial protein. In a new-born, the gastrointestinal tract is sterile, in the first few hours of life the forestomach becomes rapidly colonised with an abundant bacterial population from a variety of sources: the mother, housing, environment and feed. A normal rumen flora (bacteria and protozoa) are established by as early as 6 weeks in calves.

There are around 10^9 – 10^{10} bacteria per millilitre of rumen contents, the type and number of bacteria vary depending on the ruminants diet- for example an intensively fed beef animal on a high level of concentrates will promote a different type of bacteria to proliferate compared to an animal fed a mainly forage based diet. Protozoa are present in much smaller numbers than bacteria (10^6/ml) although due to their bigger size they may be equal to bacteria in total mass. Fungi are also present in the rumen, there role has not been fully characterised however they are capable of utilising polysaccharides and soluble carbohydrates. Fungi constitute about 10% of the microbial biomass and studies have found they are most numerous when diets are high in fibre (i.e. not cereal diets or young pasture herbage).

Digestion and Rumination

Rumination or more commonly known as chewing the cud is the process of the cattle/sheep regurgitating previously consumed feed and chewing it again. The rumen contents generally sit in two phases in the rumen: figure 4 shows the separate layers within the rumen: the lower liquid phase, this contains the finer food particles and the drier upper layer of coarser solid material. The contents of the rumen are continually mixed by rhythmic contraction of its walls. The process of rumination is when forage and other feedstuffs are forced back to the mouth for further chewing and mixing with saliva.

The stimulus which induces the animal to ruminate has been attributed to the physical stimulation of the rumen lining. Therefore diets which contain little/no coarse roughage may fail to provide sufficient stimulation for rumination. The time spent chewing the cud will largely depend on the fibre content of the food, for example in a grazing animal they will spend around 8 hours per day ruminating.

Practical tip: Roughage (silage, hay, straw) is necessary in the ration. On a forage based ration there should not be less than 40% roughage, on an intensive concentrate based ration 12% of dry matter intake should come from straw.

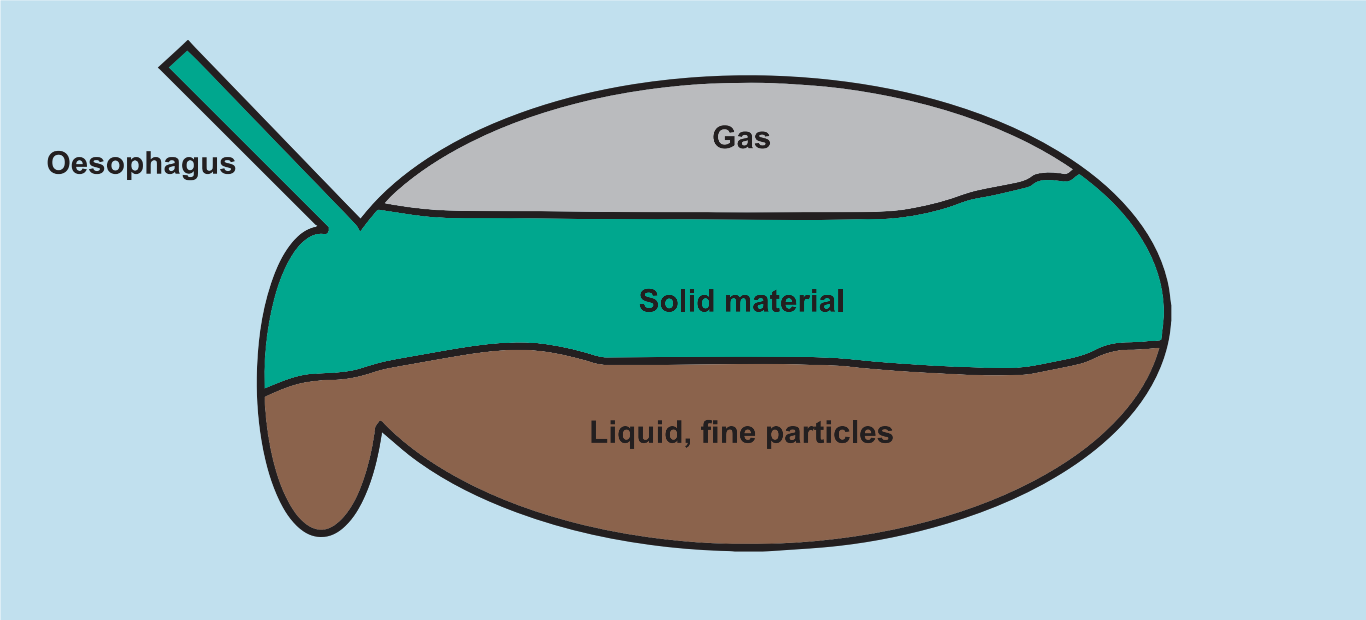
The cud is then swallowed again and passed into the reticulum, the solid part is then passed to the rumen for fermentation. The liquid portion will move through the reticulorumen to the omasum and abomasum. The rate of flow of the solid material is fairly slow and depends on the size and density of the material. As fermentation progresses the feed particles are reduced in size by the microbes which breakdown the feedstuff into the precursors for energy (VFA's).

On a high forage based ration the animal well spend more time ruminating and breaking down the forage. The plant cell wall is broken down by the microbes into carbohydrates and sugars which are then converted into VFA's, methane, hydrogen sulphide and carbon dioxide.

On a high concentrate cereal based ration, the grains contain a lot more ready digestible carbohydrates. These are more rapidly digested producing VFA's, and a higher level of propionate. This leads to a more acidic environment in the rumen and a shift in the type of microbes, leading to a decrease in forage digesting microbes. Lactic acid is also produced during starch fermentation which further decreases the rumen pH. Therefore high concentrate rations need to be carefully managed to avoid the ruminant becoming overwhelmed and unable to buffer and absorb these acids, leading to metabolic acidosis.

Practical tip: If moving stock onto a high concentrate based ration ensure this is a gradual transition. Include a source of digestible fibre (e.g soya hulls or sugar beet pulp) to ease the transition, this will help reduce the risk of acidosis.

Figure 4:



The saliva produced during chewing contains enzymes which breakdown starch and fat and is also involved in nitrogen recycling, but saliva's most important job is to buffer the pH level of the rumen. Saliva is rich in sodium bicarbonate which acts as a buffer to the acid produced in the rumen. During rumination cattle typically produce 150 litres and sheep produce 10 litres of saliva per day, however this will vary depending on the amount of time spent chewing.

Forage Analysis

Silage will form the base of most rations of livestock. In order to balance the animals requirements for energy, protein, minerals and vitamins it is vital to have the silage analysed. Due to the variability and range of factors that effect silage nutritive value you cannot rely on book values. Factors such as cutting date, weather, fertiliser application, management and maturity.

Detailed analysis can be carried out by independent feed laboratories or by feed companies. A full list of laboratories that are certified by the forage analysis assurance group (FAA) can be found here: https://www.faagroup.co.uk/

Interpreting a forage analysis:

Nutrient Value	Explanation	Target	Effecting Factors
Dry matter (g/kg)	The content of the feed minus water	Clamp = 250 – 300 g/kg Bales = 350 – 450 g/kg	Wilting period and weather
D Value (%)	Digestibility of the silage (as the % of organic matter in the dry matter)	High production stock = +65	Crop maturity, high ash content can reduce digestibility
Metabolisable Energy (MJ/kgDM)	Energy used by the animal (gross energy minus faecal and urinary and respiratory losses)	High production stock = +11 ME	Crop maturity, grass variety
Crude Protein (g/kgDM)	Known as crude as it a measure of the nitrogen content of the silage	Below 10% (100g/kg DM) will require supplementation	Type of crop, maturity, fertiliser and weather
SIP (gDM/kgLW$^{0.75}$)	Silage intake potential – estimation of how much the animal will eat if silage is the sole feed	Average silage has approx. 90	DM, digestibility and the fermentation characteristics
NDF (g/kgDM)	Neutral Detergent fibre is the amount of fibre in the silage, high NDF would indicate low energy	Ideally less than 550 g/kg DM, however if silage particularly acidic than it may be advantage to have more fibre	Crop maturity
PAL (meq/kgDM)	Potential Acid Load is a measure of the acidity of the silage (pH) and the amount of acid it produces in the rumen	<900 Values over 900 increase the risk of acidosis, reducing intakes and animal performance	DM, digestibility, lactic acid
Sugar (g/kgDM)	The sugar remaining after fermentation	Dependant on the crop DM but can range from 0-250 g/kg DM	Tend to get higher levels in dry silage due to restricted fermentation. If silage is very wet it is not unusual to have 0 sugars.
Ash (g/kgDM)	Mineral content of the silage	< 10% (100g/kgDM) above this indicates soil contamination increasing the risk of poor fermentation	If cutting bar was low or weather was wet this may increase ash content

Fermentation Characteristics:

Analysis Result	Explanation	Targets	Effecting Factors
Lactic Acid (g/kgDM)	Normally the main acid in well preserved silage	50 – 100g/ kgDM (wetter silage the higher the target is)	Clamp management, DM of silage, use of additive
VFA (g/kgDM)	Volatile fatty acids: acetic, propionic and butyric acids. High levels indicate a poor fermentation	<25 g/kgDM	Clamp management, soil contamination
pH	Low pH indicates acidic silage. High pH indicates poor fermentation (unless silage is very dry)	4.2 (for high DM silage <300 g/kg pH can be higher)	DM of silage, clamp management

Visual Assessment:
Fermentation

	Signs	
Very good	Yellowish/ khaki colour, nice vinegary smell, firm texture	
Butyric	Dark green – black colour, putrefactive (ammonia) smell, wet slimy texture	
Overheated	Dark brown – black colour, burnt caramel to tobacco smell, dry disintegrating texture	
Mouldy	Dark brown with white patches, musty smell, dry disintegrating texture	

Practical tip: A silage analysis is needed to determine the quality of the silage being fed each year. The analysis is fairly low cost and will save you money overall by avoiding unnecessary over supplementation of concentrates or ensuring animal performance is not being compromised by assuming silage is better quality than it is by not providing enough concentrates.