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Rumen Physiology for the Rancher

Ivan G. Rush
University of Nebraska - Lincoln, irush1@unl.edu

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Ivan G. Rush
Beef Specialist Emeriti, University of Nebraska
Panhandle Research and Extension Center

The ruminant animal has two unique features – it chews its cud and has four distinct compartments in the stomach. More importantly the ruminant can convert forages that are comprised by large quantities of cellulose, that is poorly digestible by non-ruminants, into high quality protein (muscle) that provides excellent eating experiences and nutrients for humans. Rumen Physiology is the study of the mechanical, physical and biochemical function of the rumen. When I first enrolled in an animal nutrition course I felt this area was unnecessary in order to feed cattle. All I wanted to learn was does the cow need 1 or 2 pounds of a supplement and didn't want to worry about the theory of the digestion in the rumen. Over the years it became obvious that the better we understand how the rumen functions in breaking down or digesting feeds the better nutrition decisions we can make in feeding cattle. Many reading this paper will already have the knowledge expressed in this paper because of college courses, attending many seminars or studying the basics. Hopefully to some it will improve their understanding how the rumen functions, how digestion takes place and what affects digestion. For others hopefully it will serve as a review. My objective in this paper will be twofold: 1) will be to discuss rumen anatomy and physiology and 2) will discuss factors that will enhance or decrease digestion and its effect on animal performance and ultimately how these factors will affect the economics of cattle production.

Rumen Physiology and Anatomy [1]

[1](From University of Minnesota Extension WW00469 and available at the following web sight: http://www.extension.umn.edu/distribution/livestocksystems/components/di0469-02.html

Anatomy of the Adult

The cow's digestive tract consists of the mouth, esophagus, a complex four-compartment stomach, small intestine and large intestine **(figure 1)**. The stomach includes the rumen or paunch, reticulum or "honeycomb," the omasum or "manyplies," and the abomasum or "true stomach."

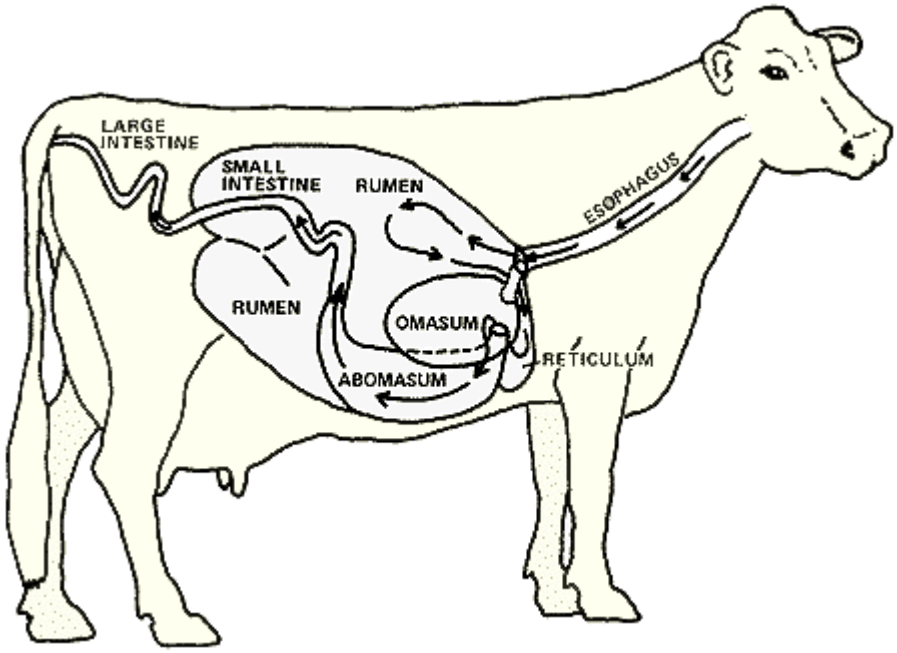

Figure 1. Anatomy of the adult digestive tract.

The rumen. The rumen (on the left side of the animal) is the largest of four compartments and is divided into several sacs. It can hold 25 gallons or more of material, depending on the size of the cow. Because of its size, the rumen acts as a storage or holding vat for feed. It is also a fermentation vat. A microbial population in the rumen digests or ferments feed eaten by the animal. Conditions within the rumen favor the growth of microbes. The rumen absorbs most of the volatile fatty acids produced from fermentation of feedstuffs by rumen microbes. Absorption of volatile fatty acids and some other products of digestion are enhanced by a good blood supply to the walls of the rumen. Tiny projections called papillae increase the surface area and the absorption capacity of the rumen.

The reticulum. The reticulum is a pouch-like structure in the forward area of the body cavity. The tissues are arranged in a network resembling a honeycomb. A small fold of tissue lies between the reticulum and the rumen, but the two are not actually separate compartments. Collectively they are called the rumino-reticulum. Heavy or dense feed and metal objects eaten by the cow drop into this compartment. The reticulum lies close to the heart. Nails and other sharp objects may work into the tissue and cause "hardware disease." If not prevented by a magnet or corrected by surgery, infection may occur and the animal may die.

The omasum. This globe-shaped structure (also called the "manyplies") contains leaves of tissue (like pages in a book). The omasum absorbs water and other substances from digestive contents. Feed material (ingesta) between the leaves will be drier than that found in the other compartments.

The abomasum. This is the only compartment (also called the true stomach) with a glandular lining. Hydrochloric acid and digestive enzymes, needed for the breakdown of feeds, are secreted into the abomasum. The abomasum is comparable to the stomach of the non-ruminant.

The small intestine. The small intestine measures about 20 times the length of the animal. It is composed of three sections: the duodenum, jejunum, and ileum. The small intestine receives the secretions of the pancreas and the gallbladder, which aid digestion. Most of the digestive process is completed here, and many nutrients are absorbed through the villi (small finger-like projections) into the blood and lymphatic systems.

Cecum. The cecum is the large area located at the junction of the small and large intestine, where some previously undigested fiber may be broken down. The exact significance of the cecum has not been established.

Large intestine. This is the last segment of the tract through which undigested feedstuffs pass. Some bacterial digestion of undigested feed occurs, but absorption of water is the primary digestive activity occurring in the large intestine.

Function of the Digestive Tract

Eructation (belching). Large quantities of gas, mostly carbon dioxide and methane, are produced in the rumen. Production amounts to 30 to 50 quarts per hour and must be removed; otherwise bloating occurs. Under normal conditions, distension from gas formation causes the cow to belch and eliminate the gas.

Rumination. A cow may spend as much as 35 to 40 percent of each day ruminating (cud chewing). The actual amount of time spent ruminating varies from very little (when grain or finely ground rations are fed) to several hours (when long hay is fed). Mature cattle spend little time chewing when eating. During rest periods, feed boluses (cud) are regurgitated for rechewing to reduce particle size and for resalivation. Feed is more readily digested by rumen microbes as particle size is reduced.

Motility of the rumen and reticulum. The rumen is always contracting and moving. Healthy cows will have one to two rumen contractions per minute. The contractions mix the rumen contents, bring microbes in contact with new feedstuffs, reduce flotation of solids, and move materials out of the rumen. Lack of or a decrease in frequency of rumen movements is one way of diagnosing sick animals.

Saliva production. As much as 50 to 80 quarts of saliva can be produced by salivary glands and added to the rumen each day. Saliva provides liquid for the microbial population, recirculates nitrogen and minerals, and buffers the rumen. Saliva is the major buffer for helping to maintain a rumen pH between 6.2 and 6.8 for optimum digestion of forages and feedstuffs.

Factors that effect digestion and performance

Negative and Positive Associative Effects in the Rumen

The rumen microorganisms are specialized in the role they play. Some bacteria "specialize" in cellulose breakdown or digestion while others are primarily responsible for starch break down. When levels of grain or starch are included into high forage diets the proportion of microorganisms primarily bacteria, will be altered as compared to the

populations found in all forage diets. The inclusion of starch (grain) in the diet will increase the level of acid in the rumen and lower the rumen pH. As this occurs the level of digestion of the forage will decrease. Small levels of grain inclusion have little effect on digestion and some data would suggest that low levels (Less than 5% of the diet will actually stimulate digestion of very low quality (less than 47%TDN) forage. When levels of grain surpass 5% of the diet forage digestibility will start to decrease with the suppression leveling off when grain reaches 50% – 60% of the diet. This does not mean we should not feed a mixture of grains and forages. Economics of the ration should determine the level of concentrate such as grains to be fed. Protein supplements can also influence forage digestion. In contrast to starch, protein supplementation will increase digestion of low quality forages that are low in protein (less than 7%). The rumen microorganisms require a source of nitrogen for growth and proliferation and the supplemental proteins such as soy or cotton seed meal are high in protein which provides supplemental nitrogen to the rumen bacteria. Once the animals protein requirement is met than additional protein is only used as a source of energy which often comes at a higher costs than feeding feeds tat are high in such as corn. In well balanced diets a combination of protein and energy are both needed to meet the cattle's requirements. If protein is adequate then energy levels will dictate animal performance – the higher the level of energy the higher the level of weight gain. Protein supplementation works similar if energy is not limited. An interesting phenomenon occurs when protein in forages is inadequate to provide nitrogen for maximum microbial activity. As grain (starch) is added up to 3 – 5 pounds to a mature cow, the cows performance may actually decrease. This is due to a shift of microorganisms from cellulose digestion, decreasing the digestion of the forage, which decreases rate of passage through the digestive tract resulting in lower forage intake and a decrease in cow performance. This is the reason that it is not recommended to supplement ear corn or other low protein feeds to with quality winter forage that is below 7% crude protein.

Some supplements are high in energy (and some moderate to high in protein) but low in starch content so can be fed with forages without having a negative effect on cellulose digestibility. Some good examples of this is the byproduct feeds where the starch or sugars have been extracted. These include the byproducts from the ethanol and corn syrup processing plants eg. distillers grains and corn gluten feed and sugar beet pulp from the sugar beet industry. These feeds contain relative high levels on energy in the form of highly digestible cellulose thus not causing a negative effect on the digestion of cellulose of forages in the rumen. Also corn distillers has relative high levels of fat of which, when fed in low levels, will provide roughly twice the energy as starch.

Influence of feed additives

Ionophores

Rumensin and Bovatec modifies the proportion of propionic acid to other VFA's in the rumen. Propionic acid is a 3 carbon VFA that is more efficient in converting to blood glucose than either acetic or butyric acid, thus resulting in more efficient energy utilization. The USDA clearance of Rumensin for beef cows is a little awkward as it states that if 150 mg. of Rumensin is fed daily intake can be cut 5% and maintain performance. If 200 mg. of Rumensin is supplemented daily then feed intake can be cut 10% and maintain the same performance. The clearance does not state that performance

will increase if fed ad libitum however reason and some data will indicate performance will increase when fed with high forage diets.

Direct fed Microbials (DFM"s)

Earlier it was felt that if large quantities of beneficial microbes were fed in large quantities of it would overwhelm the pathogenic harmful microorganisms and would improve the micro flora or the health of the gut. This was referred to as "probiotic". The term "the good bugs over the bad bugs" was very common in sales meetings. In the late 80's and early 90's, in agreement with FDA and USDA, the feed industry adopted the term of direct fed microbials in place of probiotics.

Large quantities of research have been conducted over many years investigating the benefits of DFM's on animal performance when fed in small amounts. Many different types have been fed or administered but perhaps the most popular is various strains of *lactobacillus acidophilus*. This has been offered in pastes, boluses, liquids and dry feed additives. It is generally agreed that DFM's have limited, if any effect, on ruminal fermentation of the normal healthy functioning rumen. The organisms appear to be most beneficial if delivered to the lower gut, however consistent positive data is lacking. Often these products are marketed for stressed cattle where data has shown some limited benefit.

Some more recent research has focused on propionbacteria which is a bacterium that naturally occurs in relatively high numbers in the rumen. These organisms convert lactate and glucose to propionate and acetate. This conversion would be beneficial in energy efficiency through converting propionate to glucose in the liver. It has been postulated that because this bacteria is beneficial in utilizing lactate it would aid in acidosis challenges however practically it has not been shown to decrease the incidence of grain overload or acidosis.

Fungal DFM

Perhaps one of the most researched is yeast. Yeast appears to have some modulating effect on rumen pH, possibly increasing the number of cellulytic bacteria which would increase cellulose or forage digestibility. Yeast are often fed to dairy cattle where enough concentrates are fed to lower rumen pH however dairy diets have relatively high levels of forage (40%) so forage digestion is critical to maintain high milk production. Data consistently shows some benefit in milk production when yeast is fed to dairy cows however, data is inconsistent in improving performance when yeast is fed in range diets. Many mineral supplements do contain around 5% yeast.

A fungal extract from aspergillus oryzae (amaferm is one product name) has been researched over many years with both dairy and beef cattle. Positive data is often found in milk production of dairy cows and some is found with growing cattle and cow-calf pairs however several trials have not shown any benefit.

Enzymes

Enzymes are a small protein that is very important in the metabolism in the rumen and small intestine however if fed unprotected microorganisms in the rumen will break down enzymes very rapidly. They may have some benefit in baby calves that do not have a functional rumen or perhaps in a very stressed animal. Unless some method is

developed to get the enzymes through the rumen and in the small intestine where it would be released it appears that they have limited value in cattle diets.

Dead Rumen

Sometimes the comment is made "the rumen is dead so you need to jump start the bugs". Practically the rumen always has some microbial activity and has a source of all beneficial bacteria. It is true that at times the overall population or the balance of microbe's is low however often providing a good environment for the organisms they will rebound amazing fast. Yes, some products may aid in getting them started but it must be accompanied with good management on supply of nutrients.

DFM summary

As can be noted the data seems to be very variable. In theory several products look very beneficial especially when tested in controlled conditions in the laboratory. Considerable progress has been made in the past several years and more progress will be made in the future as many leading companies are investing large sums of money into research and product development. The interest in DFM's has increased somewhat in feeding situations where the claim for 'all natural' is made. Perhaps some of the DFM's will assist in offsetting lack of performance where antibiotics and growth hormones can not be used. Perhaps one of the reasons the performance of the various products are variable is that in the healthy normal functioning rumen the small amount of the product that is fed is already present in large quantities and is overwhelmed by what is naturally produced. Perhaps another reason the data is so variable is because it appears several of the organisms are not fed at a known level. Perhaps some have been destroyed in drying, storing or the delivery process. Currently most reputable companies are guaranteeing a given count of organisms (CFU's – colony forming units) or actual content of the DFM being offered. In the future that should be required by the producer just as protein, fiber, antibiotics and ionophore levels are required on feed tags today. It appears that handling storage and use in feed processing will be extremely important in delivering a given quantity of a product to the cattle.