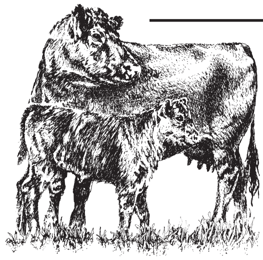

Western Beef Resource Committee

Cattle Producer's Library

Nutrition Section CL313

Beef Cattle Nutrition: Feeding the Cow and the Rumen

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Cattle and other ruminant animals have the remarkable ability to consume relatively low quality diets, yet produce high quality products such as meat and milk. The reason for this phenomenon is the incredible symbiotic relationship between the cow and microorganisms in her rumen. All parties involved in a symbiotic relationship benefit. In this case, the microorganisms are provided food in a temperature-regulated, oxygen-free environment necessary for their survival, while the cow uses the end products from microbial digestion for energy and utilizes the microorganisms themselves as a protein source. Cattle producers can take advantage of the cow-rumen relationship to produce a calf more efficiently.

This fact sheet will provide a framework for livestock managers to understand how their cattle use feeds provided to them, as well as a brief overview of how this information is incorporated into the 1996 edition (and 2000 Update) of CL300, Nutrient Requirements of Beef Cattle, published by the National Research Council (2000).

Ruminant Anatomy and Rumen Function

Cattle are sometimes referred to as four-stomached animals. More accurately, they have one stomach containing four compartments: rumen, reticulum, omasum, and abomasum (Fig. 1). The first two compartments, the rumen and reticulum, are essentially a large fermentation vat, where bacteria and other microorganisms partially break down feed. Fermentation in the rumen yields end products that the host animal can use to meet its nutrient needs.

The rumen of a mature cow is large, with a capacity to hold between 40 to 60 gallons. Muscular contractions of the rumen and reticulum mix feed with microorganisms to promote fermentation and allow for the regurgitation of feed (cud chewing) to reduce particle size. Copious amounts of saliva are produced, which helps to neutralize acids produced by microorganisms during fermentation.

The short-chained acids produced during fermentation are called volatile fatty acids (VFAs), which the cow uses as an energy source. The inside of the rumen is covered with fingerlike projections called papillae that dramatically increase the surface area available to absorb nutrients (e.g. VFAs). A severe drop in rumen pH or prolonged time at low pH can easily damage ruminal papillae and can occur as a result of excessive grain or insufficient fiber feeding.

The omasum is the next compartment that feed encounters in the gastrointestinal tract. It is located on the right side of the animal and is about the size of a basketball. Feed flows to the omasum only when it is of small enough particle size to pass through the omasal opening. Normally, particles greater than 2 mm (0.08 inch) do not pass out of the rumen. Large fiber particles in manure are an indication of improper

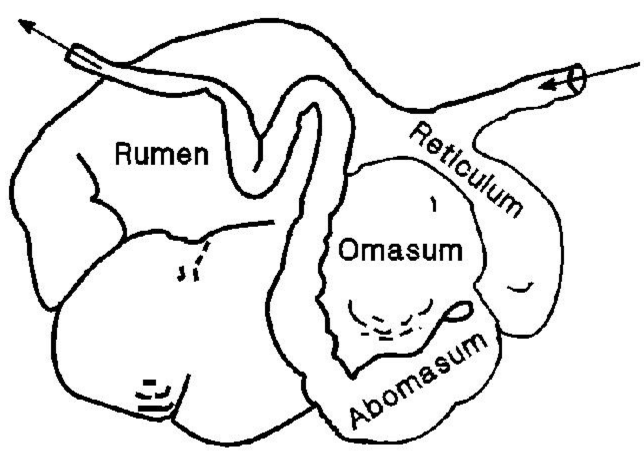

Fig. 1. Diagram of the ruminant four-compartment stomach. Kansas State University.

rumen function and should be assessed. The inside of the omasum is filled with leaflike structures that increase its surface area. The omasum is a primary site of water resorption in the forestomach.

The fourth compartment, the abomasum, contains acid- and enzyme-producing glands in its inner surface, similar to the stomach of non-ruminants. Acid and enzymes act to initiate breakdown of microorganisms flowing out of the rumen and continue digestion of feed components.

Under normal feeding conditions, the rumen will include a small gas layer on top, a middle fibrous mat layer, and a lower liquid layer. Carbon dioxide and methane are end products of fermentation that form the gas layer and prevent exposure of microorganisms to oxygen. The middle fibrous layer is a mat composed of long, fibrous dietary material that helps stimulate rumination and ruminal contractions. Dietary fiber contained in the mat layer is termed "effective fiber."

Microorganisms in the rumen are distributed throughout the mat and liquid layers. Three main groups of microorganisms are found in the rumen: bacteria, protozoa, and fungi. Bacteria are the most abundant, with over 10 million bacteria in only 1 mL (1 cc) of rumen fluid! About 1 million protozoa and 1 million fungi would also be present in that same 1 mL rumen fluid sample.

Bacteria in the rumen can be loosely grouped into fiber fermenters, starch fermenters, secondary feeders, and methane producers. Fiber-fermenting bacteria break down cellulose and hemicellulose, the structural carbohydrate components of plants (cell wall); whereas starch-fermenting bacteria break down nonstructural carbohydrates such as starch and sugars. Starch fermenters can tolerate lower pH than the other types of bacteria.

Secondary feeders and methane producers utilize end products of fermentation from the other groups in their metabolism. Generalist bacteria that can utilize both cellulose and starch are also found in the rumen. Protozoa prefer starches and sugars but also prey on ruminal bacteria, which provide the majority of protozoal nitrogen needs. Fungi are active degraders of forage and are the only rumen microorganisms able to degrade plant cuticle, which is the waxy, protective barrier on the outside surface of leaves and stems.

Healthy rumen environments are characterized by balanced interaction between the different groups of microorganisms. One example of rumen imbalance is acidosis, where starch-fermenting bacteria dominate fermentation activity and overwhelm other types of bacteria, particularly fiber fermenters. Rumen acidosis can result from overfeeding grain, underfeeding effective fiber in the ration, or some combination. With reduced fiber in the diet, rumination (cud chewing) is reduced and less saliva is produced to buffer the acids that result from fermentation.

Nutrient Requirements of Rumen Microbes

All living organisms require essential nutrients to support their metabolism. Nutrients are generally classified into water, energy, protein, vitamins, and minerals. Vitamins are divided into fat- and water-soluble categories. Minerals are further subdivided into macrominerals and microminerals (trace minerals) based on relative amounts required by the body. Macrominerals are required in excess of 100 parts per million, while trace minerals are found in concentrations less than 100 parts per million. Daily requirements for these nutrients are based on the physiological state of the animal (i.e., maintenance, growth, pregnancy, and lactation) and environmental conditions (temperature and wind speed). Rumen bacteria have similar requirements for maintenance and growth/reproduction.

Beef cattle derive the majority of the energy they require from VFAs and protein they require from the microbes that pass out of the rumen (Table 1). Rumen bacteria contain about 60 percent protein, which is highly digestible and of high quality. For example, when energy requirements are fulfilled, microbial protein can supply enough digestible protein to support up to 50 pounds of milk yield in a dairy cow. Often, when the protein (nitrogen) requirements of rumen microbes are fulfilled, the cow's protein requirements are also met. Therefore, the first goal of a cost-effective beef cow-feeding program should be to maximize microbial protein production. A secondary goal is to meet nutrient requirements not met by microbial fermentation end products.

Rumen microbes also require essential nutrients for growth, which are detailed in Table 1. Bacteria can use a greater variety of carbohydrate and nitrogen sources in support of their metabolism compared to the cow. An overview of microbial protein synthesis, a key feature of microbial growth, is presented in Fig. 2.

Carbohydrates are fermented to VFAs, which supplies energy (ATP) for synthesizing protein from ammonia (NH_3). Ammonia is available to the microbes from protein breakdown during fermentation or

Table 1. Essential nutrient sources for the beef cow and rumen microbial population.

Nutrient	Cow	Microbes
Energy	VFAs	Structural carbohydrates
	Glucose	Sugars, starches Amino acids
Protein	Amino acids	Ammonia Amino acids
	Microbial protein	Amino acids Peptides
Minerals	Dietary	Dietary
Vitamins	Dietary Bacterial	Dietary Synthesized

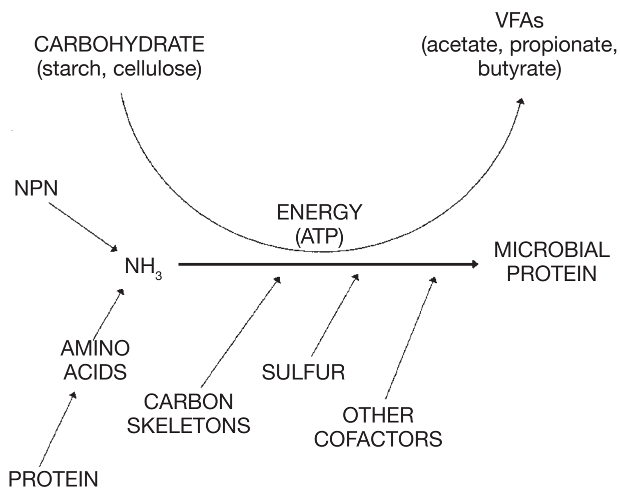

Fig. 2. Microbial protein synthesis in the rumen.

from nonprotein nitrogen (NPN) sources. A common source of NPN in beef cattle diets is urea. If any of the "ingredients" are in limited supply, microbial protein production will be determined by the availability of the most limiting substrate. In many beef cow diets based on low-quality forage, energy and protein may both be in limited supply.

Microbial protein synthesis is more complicated than just providing the correct amounts of substrate in the diet. The rumen system constantly has end products, bacteria, and feed particles being removed and new substrates added. Not only are amounts of substrate important, but availability of substrates relative to one another is also a key factor in efficient microbial protein production. Both energy (ATP) and nitrogen need to be available at the same time in appropriate amounts to allow for maximal utilization of dietary ingredients. This process is essential to the efficiency and dietary adaptability of the ruminant organism because the bulk of dietary protein digested in the abomasum of the ruminant animal is of bacterial origin.

Structural carbohydrates that make up the cell wall of plants are slowly fermented, and energy yield from these sources is minimal and slow compared to nonstructural carbohydrates (i.e., sugars, starches, etc.) that are rapidly fermented to VFAs. In contrast to structural carbohydrates, nonstructural carbohydrates can rapidly provide large amounts of energy for microbial protein production.

Many factors can influence the rate and extent of fermentation of plant carbohydrates. As plants mature, an increase in cell wall lignin occurs that makes structural carbohydrates less digestible. Rainfall, soil temperature, fertility, cloud cover, location, and cutting strategies can all influence the digestibility of plant carbohydrates. Grinding or chopping decreases particle size and thus increases surface area for microorganisms to attach to forage particles, increasing cell wall digestibility. Steam processing, extrusion, and popping will make starch more available.

Rate of passage of feed through the rumen also has an impact on the extent of digestion of slower degraded feed components. As particles pass through the rumen faster, less time is available for microorganisms to attach and break down those particles.

Like carbohydrates, dietary protein can also be separated into fractions based on rumen degradability. Proteins that are rumen degradable would be mostly broken down in the rumen to provide nitrogen for microbial protein production. On the other hand, proteins that are more rumen undegradable are resistant to microbial degradation and pass through the rumen relatively unchanged. Rumen undegradable protein is broken down and absorbed by the cow in the small intestine.

Oilseed meals, such as soybean or cottonseed meal, are examples of protein feeds with higher relative rumen degradability compared to feedstuffs such as corn gluten meal or feather meal, which are high in undegradable protein. Another nitrogen source, urea, is 100 percent degradable and rapidly provides ammonia for microbial protein production, as long as energy is in adequate supply at the same time.

Beef Cattle NRC

A difference between the 1996 and 2000 Nutrient Requirements of Beef Cattle and previous versions is that protein requirements are based on a metabolizable protein (MP) system rather than a crude protein system. The MP system allows for more efficient feeding of protein by addressing the specific requirements of bacteria and the cow. Protein is an expensive ingredient in beef cattle diets, so improving efficiency of protein use while maintaining or increasing animal performance has potential to improve profitability. Additionally, excess protein loss by the animal through urine and feces is a potential environmental concern due to nutrient management issues.

Basic to the NRC model is an estimation of the amount of bacterial crude protein (BCP; also referred to as microbial protein) that can be generated from the available diet. Rumen BCP production is predicted using dietary energy (TDN; total digestible nutrients) and nitrogen availability estimates determined by feed analysis.

The 1996 and 2000 Update NRC reports both include a computer software package containing three separate programs: a master feed library, a table generator program, and the rumen model program (Levels 1 and 2).

- The master feed program has capacity to store information on nearly 1,000 different feedstuffs, which allows the user to add new feeds or alter feed composition.
- The table generator program allows the user to determine nutrient requirements for a specifically described animal over a one-year period by month.

This is extremely useful in evaluating diets for pregnant and lactating heifers and cows. The table generator program also allows for side-by-side comparison of three different diets to the requirements determined.

• The NRC model program can be used to evaluate beef cattle diets, but the program was not designed for ration formulation. As a result of its many inputs relating to animal, management, environment, and feed analysis, there is a greater expectation of the user to have a higher level of nutritional knowledge and some appreciation of the influencing parameters.

Summary

A basic understanding of the symbiotic relationship between the cow and the microorganisms in her rumen can aid in formulating beef cattle diets. If the rumen microorganisms are provided with the nutrients they need, they will provide nutrients for the cow. The NRC model program is quite complex but can provide relatively accurate predictions of animal performance. Most ration balancing programs are based on NRC requirements, and local Cooperative Extension personnel can assist cattle producers with formulating rations for their specific situation or point them in the right direction to receive assistance.

It is important to remember that the cattle are always right! Never trust computer-generated data over what cow performance is indicating. If the diet evaluation does not fit a specific situation, producers should go back and check the inputs into the program in case a simple error has been made.

The 2000 Update of Nutrient Requirements for Beef Cattle can be purchased ($35.96 plus shipping) from the National Academies Press, 500 Fifth Street NW, Lockbox 285, Washington, DC 20055, by calling toll free 1-888-624-8373, or online from the National Academies Press website (http://www.nap.edu).

For Further Reading

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