Dairy Goat Nutrition: Feeding for Two

(How to properly feed the goat and her rumen).

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Part 1

Feeding a goat is not like feeding your dog or cat. Goats like other ruminant animals (e.g., cattle, sheep, deer and many more) have a complex digestive system where an enormous population of bacteria reside in a fermentation compartment (i.e., rumen) prior to the true stomach. These bacteria are the primary digesters of consumed feed and provide themselves and fermentation end products to the animal to meet their nutritional needs. So knowing how to feed a goat requires that you learn how to feed the bacteria that feed the goat. This article will set the stage for understanding how the rumen system works and how one should approach feeding practices to support efficient microbial fermentation.

Applied Rumen Anatomy

The rumen is actually only one chamber of a complex, bacterial fermentation system located before the true digestive stomach compartment. This is in contrast to the bacterial fermentation system located after the stomach as found in horses. Bacterial fermentation is a digestive process where bacteria living in the digestive tract partially breakdown complex dietary ingredients to produce end products, which can be used by the host animal to meet its nutrient needs. We may be more familiar with bacterial fermentation as the process by which beer and wine are produced. In addition to fermentation end products, the host animal obtains most of its dietary protein needs from the digestion of bacteria growing in its digestive tract. This bacterial digestion occurs only in ruminant animals since the fermentation process comes before the stomach.

The reticulum is a smaller fermentation compartment, in front of and intimately associated with the ruminal compartment. The reticulum is primarily responsible for assisting in rumination contractions and distributing feed within the reticulo-rumen. The rumen is the primary fermentation vat, being between 5 to 10 gallons in volume in a mature goat. Muscular contractions aid in the constant mixing of feed materials with bacteria laden fluids to promote fermentation and in regurgitation of feed materials, which results in particle size reduction from chewing and copious amounts of saliva production. Bicarbonate in saliva is primarily responsible for maintaining only a slightly acid pH in the rumen, given the tremendous amount of acids being produced during fermentation. Also as a result of the continuous fermentation process, rumen temperature is slightly greater than the goat's and can contribute to helping maintain normal body temperature during cold weather or making the goat more uncomfortable during hot weather. The rumen has a specialized lining that contains many finger-like projections called papillae, which absorb end products of fermentation, volatile fatty acids (VFAs). These VFAs, namely acetate, propionate, and butyrate, are available to the goat to be used for production of glucose (propionate), fat (acetate, butyrate) or oxidized for energy. This rumen lining can be easily damaged by severe or prolonged declines in rumen pH, a result of excessive grain or insufficient fiber feeding.

When the rumen is appropriately fed, it will contain a small gas cap, middle fibrous mat layer, and a lower liquid layer. The gas cap consists of carbon dioxide and methane, both end products of fermentation and prevent exposure of bacteria to oxygen. The fibrous mat layer is composed of long dietary fiber material that helps stimulate rumination and ruminal contractions. Dietary fiber of sufficient length (> 1 inch) to form the mat layer is termed effective fiber. The tremendous number of bacteria found in the rumen are distributed within the fibrous mat and liquid layers. Besides the type of raw material the microorganism requires for metabolism, reproductive rate also determines where the organism will be found in the rumen. Bacteria and protozoa that do not reproduce quickly in relation to rate of passage through the rumen must attach to fibrous material if they are to remain in the rumen. When effective fiber is not adequately provided, these microorganisms will be wiped out of the rumen and will result in abnormal fermentations and potentially digestive upsets and off-feed situations.

The third ruminal chamber is the omasum, which is approximately the size of a volleyball and located on the right side of the goat. The omasum is responsible for regulating particle passage rate from the rumen and water absorption from ingesta. Under normal rumen conditions, particles greater than 2 mm in size do not leave the rumen. Very little other information is known about this organ. When large fiber particles or whole corn kernels are found in the manure, this is a good indication of improper rumen function and should be evaluated. The abomasum, or fourth rumen chamber, is similar to our own stomach. Digestive enzymes and hydrochloric acid are secreted which initiate breakdown of complex proteins and starches for further digestion in the small intestine.

Table 1. Characteristics of the different categories of microorganisms found in an anaerobic fermentation system.[1]

Class of Organism	Primary Substrate	Specific Requirements	Primary Endproduct	pH Tolerance
Fiber Fermenting Bacteria	Cellulose, Hemicellulose, Pectins	Ammonia Iso-acids Cofactors	Acetate Succinate Formate, CO_2	Neutral 6.2-6.8
General Purpose Bacteria	Cellulose Starch	Ammonia Amino Acids	Propionate, Succinate, Butyrate Ammonia	Acid 5.5-6.6
Nonstructural CHO Bacteria	Starch Sugars	Amino Acids Ammonia	Propionate Lactate Butyrate Ammonia	Acid 5.0-6.6
Secondary Feeders	Succinate, Lactate Fermentation Endproducts	Amino Acids	Ammonia Iso-acids Propionate	Neutral 6.2-6.8
Protozoa	Sugars, Starch Bacteria	Amino Acids	Acetate Propionate Ammonia	Neutral 6.2-6.8
Methane Producing Bacteria	CO_2, H_2 Formate	Coenzyme M Ammonia	Methane	Neutral 6.2-6.8

[1]Adapted from Chase, L.E. and C.J. Sniffen, Cornell University.

Rumen Microbiology

Over 150 different species of microorganisms have been identified in the rumen. These organisms range from bacteria, the most abundant, to protozoa, fungi, and viruses. Although there is a wide variety of bacteria found in the rumen, they can be loosely grouped into five major categories (Table 1). A basic understanding of nutrient and environmental requirements of these different microbial groups is necessary to fully appreciate how feeding programs may impact on rumen health. Substrates, nutrient requirements, fermentation end products, and pH tolerance are shown for these different microbial groups (Table 1). One important concept to glean from this table is the observation that fiber fermentation (i.e., the bacterial breakdown of plant cell wall) occurs only at higher pH levels.

A healthy rumen is one that has a balanced interaction between all the special groups of bacteria. In abnormal rumen environments, usually one group of bacteria has overwhelmed all other groups and dominates fermentation activity. For example, rumen acidosis is the result of feeding too much grain (sugars and starches), which allows the starch digesters to overwhelm the rumen environment and eliminate fiber fermentation. Reduced dietary amounts of either effective or total fiber reduces rumination activity and salivary buffering resulting in acidic conditions impeding fiber fermentation. In addition, with loss of the rumen mat, fiber fermenting bacteria will be washed out of the rumen. This is the crux of the problem in dairy goat feeding, providing sufficient grain to support milk production without excessive amounts which suppress fiber fermentation, milk fat test, and rumen activity.

Nutrient Requirements: Goat and Rumen

All living organisms require essential nutrients to support their metabolic processes, which keeps them alive. General classification of required nutrients include: water, the most essential, energy, protein, minerals, and vitamins. Minerals can be further

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subdivided into macrominerals and microminerals based on the daily amounts required. Vitamins are separated into fat or water soluble sources. Daily amounts of these essential nutrients required are based on the physiologic state of the doe (e.g., maintenance, growth, lactation, pregnancy) and environmental conditions. Bacteria have similar requirements for maintenance and growth (i.e., reproduction).

Differences between the dairy goat and microbes are seen in where they derive their nutrients (Table 2). The dairy goat derives a majority of her energy and protein from microbial end products or the microbes themselves. Bacteria contain approximately 60% protein, which is of high quality and digestibility. In other words, the more we make the bugs grow in the rumen system, the less additional more expensive feedstuffs we need to provide the doe. Microbial protein production alone can support up to 50 lbs of milk production in the dairy cow. The first goal of a dairy goat feeding program should be to maximize microbial protein production and then secondly, meet additional nutrient requirements over-and-above those not met by microbial fermentation end products. This type of feeding approach would theoretically be the most economical and efficient.

Bacteria require a number of essential nutrients for the synthesis of protein, similar to that of the doe. However unlike the doe, bacteria can use a greater variety of potential nitrogen sources to synthesize amino acids, the building blocks of proteins. In addition, bacteria can synthesize both essential and nonessential amino acids unlike the doe, which needs to be supplied with preformed essential amino acids. Figure 1 presents an overview of the processes required to synthesize microbial protein.

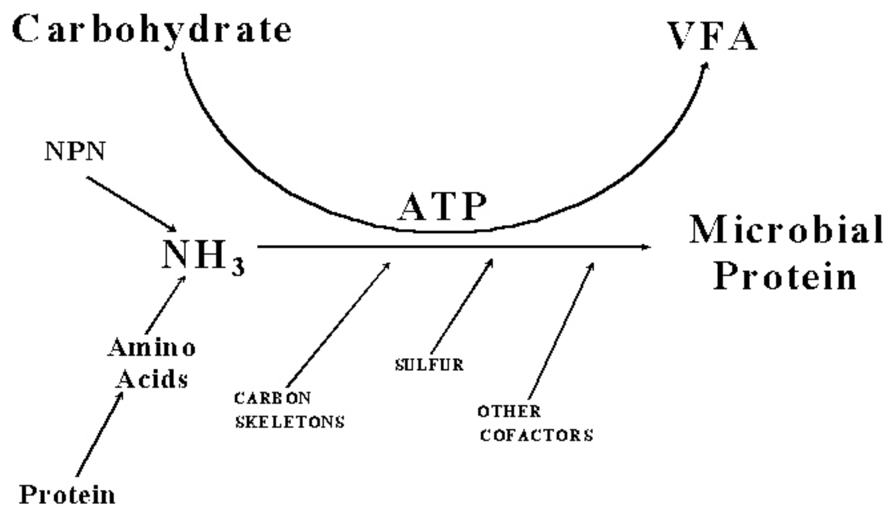

Figure 1. Metabolic processes involved in the synthesis of microbial protein.

Microbial protein production is a function of dietary ingredients, which can be broken down (i.e., degraded or fermented) in the rumen by the microbes. If any of the required building blocks are in limited supply, microbial protein production will be determined by the availability of the most limiting substrate. In many goat rations based on low quality forages, energy (ATP) and protein are in limited supply. Ammonia (NH3) may be provided from non-protein nitrogen sources, amino acids, peptides, or proteins where utilization of a nitrogen source is dependent upon the specific population of bacteria. For example, fiber fermenting bacteria can only use NH3 as their nitrogen source. Energy production (generation of ATP) will be dependent upon the available carbohydrate source (i.e., sugar, starch, or fiber) and its rate of degradation. Plant cell wall material, especially from very mature plants, is very slowly degraded and therefore is a less readily available source of energy in the rumen.

Microbial protein production is more complex than just providing the necessary amounts of substrate in the diet. The rumen is a dynamic system that constantly has fermentation end products, liquid, bacteria, and particles being removed and new substrate added. So not only do we need to address concepts of substrate requirements, availability of substrate relative to other substrates needs to be addressed as well.

Applied Feed Analysis

Microbial protein can only be synthesized when all necessary substrates are available in the rumen in a synchronized manner. Both energy (ATP) and nitrogen, the critical substrates, need to be available at the same relative time and in appropriate amounts to allow for maximal utilization of dietary ingredients and maximize protein synthesis. This process is essential to the efficiency and dietary adaptability of the ruminant organism. Remember, the bulk of dietary protein digested in the gastric stomach of the ruminant animal is of bacterial origin.

Plant carbohydrates are separated on the basis of their association to the plant cell wall (Figure 2). Carbohydrates that make up the cell wall are termed structural carbohydrates and are slowly fermented, if at all. Therefore, energy (ATP) yield from

Table 2. Substances that supply essential nutrient needs for the dairy goat and rumen microbial population.

NUTRIENT	GOAT	BACTERIA
Energy	VFA's Glucose	Complex Carbohydrates Sugars, Starches, Amino Acids
Protein	Amino Acids Microbial Protein	Ammonia, Amino Acids, Peptides
Minerals	Dietary	Dietary
Vitamins	Dietary Bacterial	Dietary Synthesized

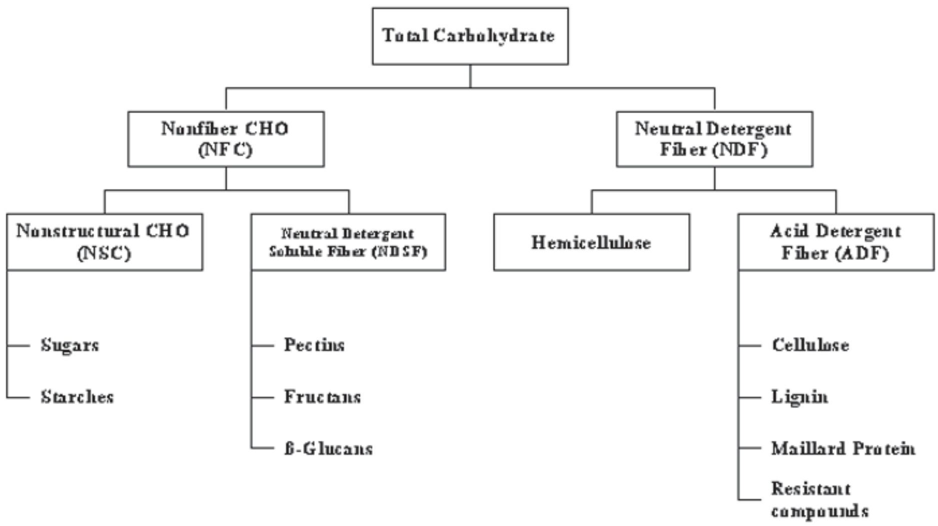

Figure 2. Partitioning of feed carbohydrate fractions.

these sources would be minimal and slow compared to nonstructural carbohydrates. Nonfiber carbohydrates (NFC) are those compounds not associated with the cell wall, with the exception of pectin. This is a diverse group of compounds including some readily fermentable fiber and traditional sugars and starches. Sugars and starches, termed nonstructural carbohydrates (NSC), are very rapidly fermented to acids and provide much energy to support milk production and growth. In contrast to structural carbohydrates, nonfiber carbohydrates can rapidly provide large amounts of energy for microbial protein production. However, fermentation of nonstructural carbohydrates also results n lactic acid production, which if excessive can have detrimental effects on rumen fermentation.

A variety of factors, which may or may not be under our control, can influence both rate and degree of bacterial breakdown of carbohydrates. As a plant matures, there is an increase in the lignin content of cell wall material making it less available. Degree of lignification and distribution of lignin within the cell wall will affect rate of digestion of plant carbohydrates. How a plant grows based on rainfall, soil temperature, fertility, cloud cover, location, and cutting strategies all can influence availability of carbohydrates within the plant. Particle size reduction (grinding) increases surface area for bacterial attachment and breakdown and is very beneficial in increasing cell wall digestion. Steam, extrusion, and popping will alter starch configuration to make it more available. Fermentation (ensiling) will make lesser available carbohydrates more available. As particles pass through the rumen faster, less time is available for bacterial attachment and degradation. Rate of passage is directly related to dry matter intake and will have an impact on extent of digestion of slower degraded carbohydrates and proteins.

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Dietary crude protein is also separated into fractions on the basis of rumen degradability and solubility (Figure 3). Proteins that are rumen degradable would be able to provide nitrogen for microbial protein production. Rumen solubility suggests that the protein source would be more rapidly available. For example urea, a nonprotein nitrogen source, is 100% soluble and degradable and therefore would very rapidly provide ammonia for microbial protein production. In meeting our goal of maximum microbial protein production, we also need to match rates of degradation of carbohydrate and protein sources to make rumen energy and nitrogen available in somewhat equivalent amounts for most efficient microbial protein yield and overall dietary protein incorporation. If we can reduce the amount of protein used in the ration and yet maintain or improve milk yield, the goat becomes much more efficient and profitable!

When putting together a goat feeding program, we need to address many of these factors in attempting to make sure that rumen availability of energy and nitrogen are coordinated in order to achieve maximal microbial protein production. We need to blend energy and nitrogen sources with similar rumen availability properties to ensure equal availability. If we maintain maximal microbial protein synthesis, not only will the amount of additional dietary protein be reduced, but the goats will have increased dry matter intake and remain healthier, all contributing to increased milk producing efficiency. When nitrogen and energy sources are not matched, diseases such as grain overload, milk fat depression, or other rumen dysfunctions may occur.

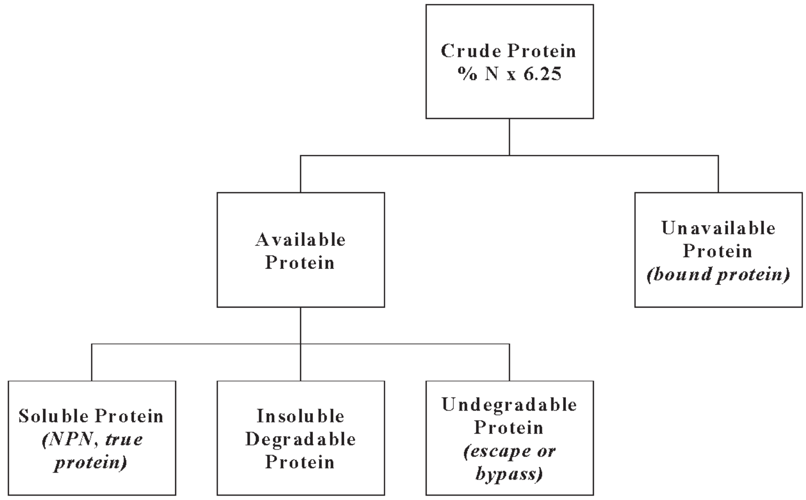

Figure 3. Fractionation of feed crude protein.

This first article provides a detailed description of the unique and exquisite digestive system of the goat that allows for consumption of low quality plant materials and generates highly nutritious food human products. Feeding practices to meet the goat's nutritional needs starts with properly feeding the rumen microbial populations, which in turn provide high quality nutrient resources to the goat in support of all her productive functions. To feed both the rumen and goat properly, we need a better understanding of feed components, namely the differing carbohydrate and protein fractions within plants to best meet microbial needs and make them efficient fermenters. It is the proper balance of fermentable carbohydrates and proteins in synchronous availability to the microbes that makes the goat highly productive and economically efficient as a production animal. The second part of this article will take these concepts and address forage quality as it would impact the feeding program for both rumen and goat.

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