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EXPERT REVIEWED

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Digestive System and Nutrient Needs of Meat Goats

Meat goats are ruminants and get the nutrients they need through a wide variety of feedstuffs. Because of this, producers must thoroughly understand digestive physiology and nutrition before they can develop an efficient and economical nutrition program for meat goats. Growth rate, reproductive performance, animal well-being, and economic efficiency of a goat operation all depend on the herd nutrition plan. This publication describes the digestive system and nutrient requirements of meat goats and the relationships between nutrition, animal productivity, and producer profitability.

Small Ruminant Digestion

A ruminant has a four-compartment stomach. Unlike monogastric (simple stomach) animals, ruminants can digest a multitude of feeds, particularly those high in fiber. The four stomach compartments that make this possible are the *reticulum*, *rumen*, *omasum*, and *abomasum* (Figure 1).

When a goat eats, the feed or forage first enters the *reticulum*. Here *honeycomb papillae* (projections in a honeycomb pattern that line the rumen) help separate particles based on size. Large feed particles are sent back into the rumen for further digestion, and small particles are sent to the third digestive compartment. Large particles can also be regurgitated and re-chewed to make them smaller so that they are easier to digest.

The most well-known gastro-intestinal compartment of the ruminant is the *rumen*. The rumen is a large fermentation vat where fatty acids, carbohydrates, proteins, and other nutrients are broken down. Microbes within the rumen help break down nutrients from feed-

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stuffs that the animal's digestive system otherwise cannot metabolize, like the fibrous components of feeds. Hemicellulose and cellulose are fibrous carbohydrate that animals cannot digest; rumen bacteria have the proper enzyme to degrade the molecules. This stomach compartment allows the ruminant to digest forages that nonruminants cannot.

The bacteria of the reticulum and rumen do more than simply help break foods down. They synthesize B-complex vitamins and volatile fatty acids (VFAs). Microbes also allow the ruminant to use lower-quality protein sources to meet its needs; this means that the quantity of protein in a ruminant's diet is much more important than quality.,

The microbial flora inhabiting the rumen of a goat changes with the goat's diet. Goats that consume a high-forage diet have a microbial population different from that in goats fed a high grain diet. This difference in microbial populations in individual goats is the main reason that dietary changes should be made gradually over the course of 10 to 14 days. Rapid dietary changes could result in acidosis, ketosis, urinary calculi, and other diseases discussed in later sections of this publication.

The third organ, the *omasum*, helps filter the food being digested and removes water that is absorbed through the folds of the omasum. The omasum pushes the food toward the *abomasum* for the last stage: complete chemical digestion.

Chewing of "cud" is a well-known characteristic for ruminant animals. Rumination is regurgitation of ingested food by *reverse peristalsis* (movement from the digestive tract to mouth), followed by remastication or re-chewing. Then, finally, the re-chewed food is swallowed a second time. This process more efficiently breaks down roughage and increases its surface area to aid microbial fermentation in the goat's digestive system. Goats generally ruminate when they are not exercising or eating. Rumination and grazing are inversely related: the more time spent grazing, the less time ruminating, and vice versa. Goats spend a considerable amount of time each day ruminating.

As the microbes begin the fermentation process, they generate a substantial amount of gas. *Eructation*, or belching, is how ruminants release fermentation gasses. If eructation is inhibited, the rumen begins to expand and can cause bloat.

The "true stomach," or the *abomasum*, is analogous to the stomach in the monogastric animal. The ruminant's abomasum has many of the same digestive enzymes and functions as the monogastric's stomach. Here chemical digestion occurs in a low pH environment with the aid of digestive enzymes such as trypsin, pepsin, and chymotrypsin. Bicarbonate is also present and buffers the stomach's pH to protect the stomach lining.

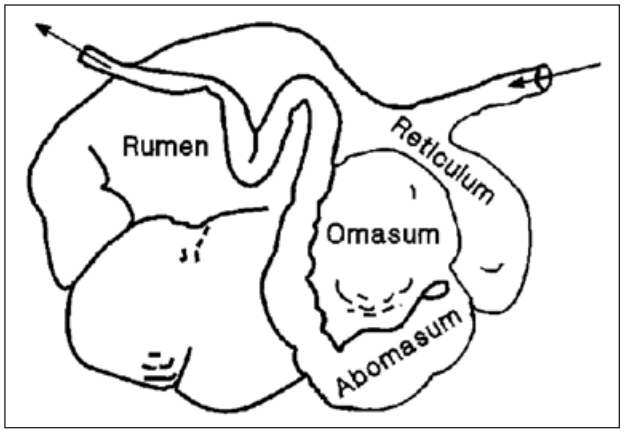

Figure 1. Schematic of ruminant digestive tract *Photo courtesy of Kansas State University.*

It is critical to note that the ruminant animal is not born with a functioning rumen. For several weeks, the kid relies on the abomasum only. This is due to the kid's primarily milk-based diet. The milk bypasses the rumen, reticulum, and abomasum via a structure called the esophageal groove. If milk enters the rumen for fermentation, the resulting products are useless and detrimental to the kid.

Essential Nutrients

While a goat can survive on many different types of feeds, the essential nutrients in every goat's diet are water, energy (fat and carbohydrates), protein, minerals, and vitamins.

Water

Water is the cheapest and most essential of all the nutrients. However, it is often the most overlooked. Water's many important roles within the body aid the animal in daily function and survival. On a larger scale, availability of water can determine size and efficiency of a goat operation.

Goats, like all animals, have three sources of water. The first is drinking water, which is the water provided by the producer or from a natural water source. The second source is water within the feed, which can be significant when goats are consuming high-moisture feeds, such as silage. The third, and least significant for small ruminants, is metabolic water. Metabolic water is the water generated by the catalysis (breakdown) of other nutrients.

Water restriction can decrease goat productivity. Severely dehydrated goats may eat less and, ultimately, produce less. From a management standpoint, water intake must be proportional to feed intake. The more water that is available, the more likely the animal is comfortable and eating. During dehydration the goat's heart rate and respiration rate rise, ultimately causing the animal's body temperature to rise. Signs of dehydration can be, but are not limited to panting, pale gums, sunken flank region that exposes the hips, and a lack of skin elasticity. A high fever plus disrupted bodily functions caused by lack of water can result in the death of a goat.

Goats need 0.75-1.5 gallons per animal per day. However, this amount can vary drastically depending on season, climate, and production stage. Producers should provide ample, fresh, and free-choice water. During winter, ice-free water should be available at all times to goats. To eliminate competition for water, make sure there is ample space at troughs or fountains for your herd.

Energy

Energy is most often the limiting nutrient in a goat's feeding regimen. There are two main sources of energy in nature: carbohydrates and fat. Excess dietary protein can also be an energy source. Sugars and starches are carbohydrates and constitute approximately 65% to 75% of the total energy from forages. Goats and other ruminants can digest the starches from plants because microbes possess the catalytic enzyme, cellulase, which can catabolize cellulose, the major carbohydrates in plants. Rumen microbes use cellulose and produce volatile fatty acids (VFAs) as a waste product. Ruminants then use VFAs as an energy source.

When compared to starch or sugars, fats offer 2.25 times as much energy per gram. Although fat is high-energy, it should comprise no more than 6% of a goat's diet. Too much fat can harm the microbial population in the rumen.

Several different methods can be used to quantify the level of energy needed by a goat or contained within the feed. The two primary methods are described in the following text.

Total digestible nutrients (TDN), is a measurement of the energy value of a feed or ration. Most commonly, TDN is expressed as a percent of a feedstuff. It can also be described as absolute (pounds) needed by an animal. TDN can be calculated by taking the sum of digestible crude protein, fat, crude fiber and nitrogen-free extract (starch). TDN does not account for the energy lost from urine, gas, and heat.

Net energy is nearly always the most accurate system for describing the energy needs of the animal. Net energy is the energy available to the animal after accounting for energy loss. This system is more accurate because it takes into consideration energy losses in feces, urine, gasses, and heat (produced during fermentation). It is more accurate than TDN for determining energy needs for goats, but is difficult to estimate and not always practical.

Protein

Proteins are crucial to a goat's development and are involved in in most biological processes. Proteins are made up of long chains of individual amino acids. The way the amino acid sequence is "read" is specific, just as people read English sentences from

left to right. These building blocks determine the protein's function within the body. Protein aids in the synthesis of new tissues and repair of old tissues; therefore, protein is very involved in rate of gain, repair of tissues after pregnancy, and lactation.

In terms of nutrition, protein is the most expensive nutrient to feed. Proteins must also be fed carefully, because both a deficiency and surplus can lead to problems. For small ruminants like goats, protein quality is not as important as it is for nonruminants. Microbes within the rumen (which nonruminants do not have) allow for utilization and digestibility of low-quality protein in ruminant animals.

All the protein present within the feed is called *feed intake protein*. Feed intake protein can be further divided into *degradable intake protein* (DIP) and *undegradable intake protein* (UIP). DIP is the portion of the protein source that is available for the microbes to modify during digestion in the rumen. Microbes convert DIP into bacterial protein. UIP is the portion of the protein source that is unavailable to the microbes for digestion and remains unchanged when it reaches the abomasum and small intestine. DIP and UIP must be in balance with each other to have a healthy rumen where the flora is maintained and the goat absorbs nutrients—so the goat is healthy.

The combination of bacterial protein and UIP that reach the small intestine is called *metabolic protein* (MP). As mentioned earlier, UIP enters the small intestine unchanged. Metabolizable protein is then absorbed into the bloodstream to be used by the goats.

For does, the recommended amount of crude protein varies widely throughout the production cycle, depending on whether they are open, pregnant, or lactating. Protein requirements for kids vary by stage of growth. Goats on high-quality hay or grazing forage generally do not need an additional protein supplement. The rumen microbes efficiently convert forage sources to protein for the goat's use. Sources of feedstuffs that meet the needs of goats are high quality forages (hay and alfalfa) and plant meals (soybean and canola).

Nonprotein nitrogen (NPN) is another source of protein for goats. NPN can be used in ruminants because microbes in the rumen can take nitrogen-containing compounds (such as urea) and convert them into free amino acids.

Minerals

Minerals are classified into two categories based on the amount required: macrominerals and microminerals (trace minerals). Macrominerals are required in larger amounts and are expressed as percent or absolute. Microminerals are needed in smaller amounts, such as parts per million.

Essential minerals for goats include calcium, phosphorous, sodium, chloride, magnesium, zinc, copper, iodine, and selenium, and should be accounted for when feeding goats. The ratio of calcium to phosphorous is important when feeding male meat goats and should be at least two parts calcium to one part phosphorous to help prevent urinary calculi.

Minerals can be provided in several different forms with advantages and disadvantages for each. Loose feeding or free-choice is an efficient and popular method to offer minerals to the goat herd, but can be disadvantageous because of variation in animal-to-animal consumption. Mineral blocks are also used to supply minerals. Both of these methods prevent the producer from quantifying the amount consumed per individual. If minerals are to be incorporated into the goat's diet, be sure to purchase high-quality minerals designed for goats. The minerals should be provided to the herd in a weather-protected delivery device.

Minerals can also be provided within a *total mix ration* (TMR) or a pre-mix. In TMR feed the minerals are mixed in at a determined amount. A pre-mix is composed of a specific mineral or combination of minerals that the producer then adds to his/her

feed. A TMR or pre-mix can be a more accurate management method, but is not possible in unsupplemented grazing animals. Injection of minerals is also an option when a specific mineral is known to be deficient. Injections allow the producer to deliver the exact amount each individual needs and to cater to different production stages.

Vitamins

There are two classes of vitamins based on solubility properties. Those that dissolve in fats are called "fat-soluble" vitamins. Vitamins that dissolve into water are termed "water-soluble" vitamins.

Fat-soluble vitamins are A, D, E, and K. Microbes produce byproducts that include Vitamin K, so that vitamin does not need to be incorporated into goats' diets. Vitamin K is integral for blood clotting by aiding in the formation of prothrombin. The remaining fat-soluble vitamins are considered essential; they must be included in the diet. Vitamin A is primarily involved in vision development and is the source of retinol. Vitamin D is a hormone, but was coined a vitamin first, as it is imperative for bone formation. Vitamin D is synthesized when the animals are exposed to sunlight and supplementation is not necessary. A major antioxidant within the body originates from Vitamin E. Vitamin E also plays an integral role in reproduction. This vitamin has a unique relationship with selenium that is explained in the "Nutritionally Caused Diseases" section later in this publication.

Ruminants do not usually require water-soluble vitamins (B-complex vitamins) in their feeding regimen, because microbes in the rumen produce adequate amounts of these water-soluble vitamins under normal circumstances. Water-soluble vitamins only need to be supplemented in special circumstances. However, one B vitamin that can be of concern is B1 or thiamine, which can result in the condition, polioencephalomalacia, which is further explained in the "Nutritionally Caused Diseases" later in this publication. Vitamin C is not required in the diet, because goats synthesize adequate amounts with normal metabolism.

Many vitamins are recommended in units defined as the *international unit* (IU). The international unit is used in pharmacology to define the biologic activity or effect of a substance. Vitamin A requirements are described by the units entitled retinol equivalents.

Common Nutritional Diseases

Nutrient mismanagement can lead to nutritional diseases that may result in production limitations. A more in-depth discussion of common diseases in goats can be found in the Purdue Extension publication, *Common Diseases and Health Problems in Sheep and Goats* (AS-595-W).

A well-fed meat goat has a fleshy appearance, a shiny hair-coat, and a normal growth curve. The goat is bright and alert. Signs of an unhealthy meat goat include bones that are visible through the coat; a dingy, rough hair coat; slow growth when compared to herd mates; poor milk production; and lethargy resulting in decreased feed intake.

A healthy Boer goat. *Photo courtesy of Western Illinois University*

Urinary calculi is a condition common to intact male goats. It is a metabolic disease where calculi (stones) become lodged in the urinary tract. These "stones" are generally comprised of phosphate salts. This disease arises when low-roughage, high-grain diets are fed, preventing phosphorous from being recycled and causing a build-up in the urinary tract. Male goats are more prone to this condition because of the structure of their reproductive tract. Maintaining the appropriate ratio of Ca:P (2:1) in the ration is an effective way to prevent urinary calculi. Fresh water is imperative to preventing urinary calculi, as a dehydrated goat has more concentrated urine, making stone formation more common.

Acidosis occurs when the goat consumes a high amount of starch. An alternate name for this condition is "grain overload." If rumen microbes are not adapted to a high starch diet, the lactic acid pro-

duced by starch breakdown is not used fast enough to prevent acidic conditions in the rumen. Acidosis can be acute or sub-acute, and can lead to secondary problems. The acute form can have serious implications and result in death. Sub-acute conditions can cause scours, decrease appetite, and hoof problems such as founder.

Ketosis is a condition where a fat imbalance occurs from a high concentration of ketone bodies. This condition affects does during late gestation when the dam is unable to meet the glucose demand for the fetuses (or fetus) and her own metabolism. A doe with two or more fetuses is especially susceptible to this condition. A reduction in glucose causes the doe to metabolize her fat stores at high levels, leading to fatty acid production, and, ultimately, ketone body production. Ketones at hyper-elevated levels in the bloodstream can be toxic, hence the term toxemia. In severe cases, does are too weak to stand and eventually die. The doe must have a balanced diet, including high-energy (carbohydrate) feeds to prevent this condition.

Grass tetany affects goats deficient in magnesium. This can affect any ruminant animal, especially those grazing on rapidly growing grass in the spring. While animals may die before showing symptoms, signs a producer should be aware of are incoordination, staring, thrashing, and general loss of body control. Pasture rotation and pasture management can eliminate this deficiency.

White muscle disease is correlated to selenium imbalance and, because of the interdependence on vitamin E, a vitamin E imbalance. This degenerative muscle disease is common in developing kids. White muscle disease can affect skeletal muscles or heart muscles, or both. Skeletal muscle that is affected causes a stiff gait due to a hunched back. When the heart muscle is affected, the goat may present frothy, blood-stained nasal discharge. Selenium deficiency can also affect an individual's immunity, reproduction, and vigor of kids at birth. White muscle disease can be treated with an injection of both vitamin E and selenium. Vitamin E and selenium are generally included in the ration or mineral pre-mix.

Goiter is an iodine-deficiency symptom of and results in a hypertrophied (enlarged) thyroid. The thyroid is found in the throat region and, when iodine-deficient, appears as a large "bulge" at the throat. The thyroid becomes enlarged because it must work harder to obtain small amounts of iodine present in the diet. States surrounding the Great Lakes contain soils deficient in iodine, therefore iodine should be included in rations.

Night Blindness originates from a deficiency in vitamin A. Vitamin A is vital for vision. Vitamin A is also most likely to be deficient when older stored hays are fed.

Polioencephalomalacia results from thiamine deficiency or sulfur toxicity and literally means, "softening of the brain." This condition can be caused by high-carbohydrate diets or by eating excess amounts of sulfur compounds. Sulfur produces thiamine-like compounds called analogs that decrease the absorption of thiamine in the rumen. Sources of excess sulfur include water and by-product feeds from the ethanol industry. Total sulfur content in a diet should not exceed 0.3% of diet dry matter.

Evaluation of Feeding Program

The feeding program can be evaluated by body weight, quality of hair coat, and productivity of the individual. However, an efficient way to evaluate a goat herd is by body condition scoring (BCS) the animals. For an in-depth discussion on BCS refer Purdue's Extension publication, *Body Condition Scoring in Farm Animals* (AS-550-W).

Producers using the BCS system judge a goat based on key anatomical points and the fat depots over each point. The greater the fat deposition over a certain point, the higher the BCS score. Generally, a healthy and high-producing goat scores from 2.0 to 3.5 over the course of the production cycle. Producers arrive at a BCS by either looking at a stationary animal or running a hand over each critical point. The nutritional needs throughout development and during the production cycle vary, just as the BCS does. A doe at weaning should score 2.0 to 2.5, while at late gestation she could score 3.5. Moving from 2.0 to 3.5 equates to about 8–10 pound fluctuation in body weight. The BCS should match the production stage of the goat and their nutrient needs.

The second method a producer might use to properly manage a goat herd is quantitative and requires accurately maintained records. Each individual animal has its own set of records that includes, but is not limited to, de-worming schedule, amount of feed, weight, and breeding schedule. For a production system, feed consumption can be difficult to manage, but is practical given the limitations associated with individual records.

Often a producer discovers it is a combination of these methods, in addition to close observations of his/her goats that allows for a productive, efficient, and healthy herd. Once these basic management practices are implemented, the chance of mismanaging a goat's diet and dealing with the resulting consequences are minimized.

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