

Practical small ruminant nutrition: Applied nutrition for veterinarians

Andrea Mongini, DVM, MS

M&M Veterinary Practice, Inc.
Ewetopia Dairy, Inc.
Denair, CA 95316

Abstract

Small ruminants have unique nutritional requirements that vary from cattle and other ruminant species. Sheep and goats also differ from one another in their nutritional requirements. This paper covers concepts related to basic applied nutrition for feeding goats and sheep. The nutrition recommendations covered are for practical use by veterinarians who aim to assist clients in creating feeding guidelines.

Key words: small ruminant, goat, sheep, nutrition

General nutrition concepts

As small ruminants, goats and sheep function similar to cattle in terms of rumen metabolism; however, there is more to nutrition than digestion, and this is where interspecies differences arise. Goats are browsers by nature and their rumen is better adapted to digestion of leaves and plant material. Sheep, like cattle, prefer to graze and will consume grasses preferentially to browse. The variation in plant preference has a large impact on eating behavior which is very important to consider when creating diets and evaluating rations.

As browsers, goats use their lips to carefully select and sort feed. They prefer high-starch, high-pectin, low-fiber diets. They are excellent at rejecting moldy, spoiled and low-quality feed to the point of starvation.

As grazers, sheep are much less selective with their feed preferences. They will avoid low-quality, coarse feeds when higher quality forage is available, but are more likely to tolerate poor-quality feed if it is the only option available. These differences make evaluation of diets quite different between species, and it is paramount to the foundation of understanding small ruminant nutrition. If we do not account for animal behavior and preferences, even the most nutritionally appropriate diet may never reach the animal's rumen if they are not interested in ingesting it.

Goats and sheep consume a higher percent of their body weight than cattle. This is an important and unique difference, especially when utilizing cattle nutrition models to formulate small ruminant diets. During growth, kids and lambs consume approximately 5% of their body weight (BW). Lactating does and ewes will eat up to 6% BW, while dry, pregnant does or ewes eat 4% and close ups should eat 3% when close to parturition.

The rumen

Experienced nutritionists will say that you feed the rumen, not the ruminant. The rumen is a large, fluid-filled fermentation vat filled with billions of bacteria, protozoa, fungi and archaea living in the rumen. It is often referred to as the rumen microbiota. A key feature that makes ruminants unique is their ability to digest roughage (hay, grass, leaves, etc.) and turn these low

nutritional value feedstuffs into amino acids, volatile fatty acids and essential vitamins which can eventually lead to meat and milk production. The goal of feeding a goat or sheep is to optimize rumen function, provide substrates that support microbial fermentation, and deliver essential nutrients and minerals required for health and production.

Fiber, carbohydrates and starch

Fiber is the most important feed ingredient for ruminants because microbes turn fiber into amino acids which can be utilized for protein or volatile fatty acid (VFA) production. Quality, quantity and presentation are of equal importance. Understanding the different types of fiber and how they are digested is of little importance if animals are being fed hay on the ground, in mud or in an overcrowded manger. They will use hay as bedding to have a dry place to lay down and the feed will be wasted.

The main sources of fiber in a sheep or goat diet are hay, pasture (grasses, clover, etc.) and leaves (browse). Plants produce different types of fiber in the leaves, stems and stalks as they mature. Young plants have more digestible fiber and older, more mature plants tend to have more undigestible fiber. Digestible fiber is measured as acid detergent fiber (ADF) and neutral detergent fiber (NDF). The undigestible fiber portion is called lignin, which is structural fiber for the plant. Straw bedding has a very high lignin content while young grasses have a very low lignin content. Sheep and goats prefer to eat roughage that has a lower lignin content which translates to less retention time in the rumen. However, the rumen fiber mat houses much of the ruminal microbiome and maintaining adequate fiber levels helps to maintain populations of productive, "healthy" microbes. Animals compensate for low lignin diets by increasing the volume of feed that they consume. The rate of passage of feed through the GI tract is higher for a low fiber or low lignin diet because it is more rapidly digested in the rumen. A diet containing more mature roughage will have a slower rate of passage since it takes longer for the microbes to break down this form of fiber. As you can imagine, there are scenarios where both fiber types would have an advantage. A doe or ewe that is heavily pregnant has limited rumen volume due to a very large uterus, and has exceptionally high energy requirements to support the growing fetuses while producing colostrum for impending parturition. In this situation, she should be eating a low-lignin diet with high rate of passage. Animals with maintenance metabolic requirements, such as those living as pets or non-breeding animals need a high-lignin diet to provide satiation without excessive calories leading to weight gain. As previously discussed, behavior plays a large role in forage ingestion for small ruminants and selecting a feed that the animal will eat and not refuse is an important consideration.

Roughage can be physically evaluated to make a basic nutritional assessment.

Hay should smell fresh and look green, not brown, yellow or grey. The hay should come apart easily into flakes, but not compressed, hard flakes. Shattered or dry hay was baled too dry, and goats and sheep will reject it from a palatability standpoint even if it is good quality in a lab analysis. Compressed alfalfa flakes or discolored brown hay imply the hay was too wet when it was baled. Alfalfa hay moisture > 15% or grass hay moisture > 14% is too high and problems will occur when feeding this hay. High moisture at baling can cause molding, even if you cannot visually see mold colonies. It also heats the hay in the bale which causes the Maillard reaction to occur. This reaction alters plant protein to an unavailable form. It is commonly known as caramelized, or tobacco hay, and while it will have a sweet smell which animals like to eat, it has poor nutritional value.

Nonstructural carbohydrates

Carbohydrates have a close relationship to protein levels in the diet. Rumen microbes utilize cellulose, starch, sugars, pectins and many other carbohydrate forms to produce glucose. The glucose present in the rumen allows many different microbes to proliferate and is essential for protein metabolism, VFA synthesis, and lactose production. A nitrogen source (protein) and a carbohydrate source (roughage, grains) with similar levels of digestibility will produce the most efficient rumen metabolism. Excessively high-starch and grain diets with low roughage are precursors to ruminal lactic acidosis. Enterotoxemia can be a common sequelae to grain overload or lactic acidosis. A common scenario in which goats or sheep are limit fed fiber while consuming excess grain is with show Boer goats and market lambs. Unfortunately, rate of gain is reduced when fiber is limited and the risk of acidosis or enterotoxemia increases. This is primarily due to limiting the fiber substrate for microbial growth and secondarily due to a proportionally higher amount of grain (NSC) in the diet which leads to both clinical and sub-clinical rumen lactic acidosis.

Nonstructural carbohydrates (NSC) are sugars, starch and organic acids. Goats tolerate higher NSC levels than cattle and sheep. NSC levels up to 28-32% work quite well in lactating doe grain diets as long as the sugar content is high. Starch levels of 24-26% are acceptable is the sugar content is 6-8%. Lactating sheep usually are fed concentrates with 26-28% NSC but the starch level should ideally be 24%. There are significant regional differences in the amount of sugar in diets. We tend to feed higher amounts of sugars and pectins in the western U.S. than the eastern U.S. due to more access to byproduct commodities. The high sugars and starches in goat diets reflect their browse adaptation while sheep follow cattle requirements for NSC more closely. During late gestation, both sheep and goats require a higher NSC level to support fetal maturation and colostrum production. Keep in mind that while cattle generally have single calves and sometimes twins, multiple fetuses are common in sheep and goats. These animals can produce 3-4 offspring without major health concerns if fed properly.

In my experience, growing kids and lambs do best on a grower grain ration with 22% NSC and a starter grain with 24% NSC.

Protein

It is estimated that 60-75% of a small ruminant's protein requirement comes from microbial production of amino acids and digestion of microbes when they get washed out of the rumen and into the abomasum. Some research suggests close to 90% of a ruminant's protein requirement comes from microbes. A healthy rumen with a good fiber mat can produce more protein for the animal than simply feeding a high-protein diet with little or no fiber.

When it comes to feed ingredients, protein is generally measured as crude protein (CP), which is the nitrogen content of the feed multiplied by 6.25 (the nitrogen content of protein). This can be confusing because grass hay and urea can have a high CP value due to a high nitrogen content even though there is little (grasses) or no (urea) actual protein in the feed. This is called soluble protein or non-protein nitrogen (NPN). The percent soluble protein is a way to measure how much of the crude protein is in a non-protein form. Rumen microbes can utilize NPN to make amino acids, but they need a source of carbohydrate. The microbe's goal is to procreate more microbes. To do this, they require a carbon, hydrogen, and nitrogen source to synthesize microbial protein. High-soluble nitrogen without a rapidly digestible carbon-hydrogen source (NSC) creates a toxic rumen environment that kills microbes. Urea toxicity often occurs when excessive urea is fed without a carbohydrate source. The carbohydrate source must be rapidly digestible (such as ground corn, barley or molasses) and present in the rumen at the same time as the NPN from grasses or urea. When feeding a high-protein diet containing alfalfa or soybeans, a slower digesting form of carbohydrate (such as cracked, rolled or whole kernel corn) can be fed to accommodate the slower rate of digestion of these proteins. When the protein or nitrogen source and the carbohydrate digestibility are mismatched, neither nutrient is efficiently digested leading to suboptimal amino acid and VFA production and more nitrogen waste in the system.

Protein requirements for various life stages

The following recommendations are based on personal experience and field research. If grazing or roughage do not provide adequate protein for the animal, supplementation is required during growth, pregnancy and lactation for optimal production and health. The protein level in the diet needs to equate to 18-20% for growth, 17-18% for dairy lactation, 15% for meat breed lactation, and 14% for maintenance (non-pregnant, pets). The dietary protein recommendation must consider both roughage and grain sources.

Physical or visual assessments of dietary protein status include growth rate in youngstock, body condition score, milk protein level, fertility and lambs or kids per litter. Low-protein diets create kids or lambs with poor or frail skeletal development. These animals often have short stature and/or thin long bones (legs). In adults, you will see high incidence of singles or low fertility in breeding males and females. High-soluble protein can lead to loose, cow-pie like feces and is most commonly seen in sheep and goats grazing lush spring grasses or high-quality grass hay. This is a very important concept to understand. Grasses have a high nitrogen content. Urea is also an example of a non-protein nitrogen (NPN) source, while alfalfa or soybean meal have a high true-protein content. Loose stools are seen when there is a high nitrogen or protein content in

the feed and a low carbohydrate (NSC) level in the diet at the same time. We also see diarrhea associated with grain overload events which are due to a very high NSC level often combined with a comparatively lower nitrogen or protein level in the diet. It is important to differentiate between these 2 scenarios when making nutritional evaluations.

Fat

The rumen is not capable to metabolizing fat in high levels. Fatty acids can be digested at low levels, but the rumen is a fermentation vat with a neutral pH. It is not designed to process high-fat diets. Dietary fat is measured as crude fat on feed tags and often as ether extract in lab analyses. Most dietary fats fed to small ruminants are in the form of plant or seed oils. These are unsaturated fatty acids which need to be saturated in the rumen to be utilized by the ruminant or stored as adipose. Certain plant oils or fats such as cottonseed, sunflower and corn oil have high levels of trans fatty acids. The rumen has a limited capacity to fully saturate these oils. The result is partial biohydrogenation which leads to specific trans fatty acid production. This process will suppress de novo fatty acid synthesis in the udder. The result is an observed milk fat depression; a common issue with dairy goats and sheep.

High-fat diets overwhelm microbial systems and can coat the fiber in the rumen, making it less available for microbial digestion. The crude fat level should be below 5% in the total diet. Show animals often have inappropriately high levels of fat in their diets in an attempt to enhance weight gain. These diets may contain greater than 10% fat and the rumen will effectively stop functioning due to microbial death. A current trend among small ruminant pet owners and show breeders is to feed high levels of sunflower seeds to improve coat quality or boost milk fat. Sunflower seeds are high in trans fatty acids which can overwhelm the microbes' ability to saturate these fats leading to decreased rate of gain, milk fat suppression, and overall poor rumen digestion.

Minerals

Trace elements are important for small ruminant health and should be supplemented to all life stages. Mineral requirements are regional due to variations in soil and feed composition. Copper, zinc, and selenium are the minerals of most importance in terms of health consequences and likelihood of problems if over or underfed. There are important mineral interactions that must be accounted for as they can interfere with the absorption of Cu, Zn and Se. Molybdenum, iron and sulfur can interfere or prevent absorption of these key minerals.

Copper

Copper metabolism and its interactions are a complex topic that receive significant attention from producers. Copper is essential for immune system function, neural development, ligament and collagen formation, and hair or wool growth and pigmentation. Sheep and goats have different requirements for dietary copper. Sheep are more efficient at absorbing and retaining dietary copper due to differences in binding proteins in the liver. For this reason, their dietary copper requirements are significantly lower than goats. Copper concentration in sheep diets should be approximately 10 ppm. They will begin accumulating copper in their liver when dietary levels exceed 15-20 ppm. Goats require closer to 15 ppm of copper in their ration

and will accumulate copper in their liver when the diet concentration exceeds 20-25 ppm.

Molybdenum and copper interactions

Molybdenum binds and prevents copper absorption in the GI tract. An ideal ratio of Cu:Mo for goats is 10:1. Different parts of the United States have soil Mo ranging from 0.1-5 ppm. This means that in order to maintain a dietary 10:1 ratio, the dietary copper for a goat might need to be 50 ppm if the molybdenum level in the diet is 5 ppm. Your local extension specialist is a good resource for information related to copper, selenium and molybdenum levels in local feedstuffs in your region.

Sheep that are fed goat diets will accumulate copper and are at risk of copper toxicity while goats fed sheep diets are at risk for copper deficiency. Copper toxicity is fairly common in goats and sheep in the U.S. Many grain mixes produced for sheep and goat consumption contain toxic levels of copper. Copper toxicity is often overlooked by producers and veterinarians since one of the common presentations is acute death after 1-3 days of lethargy. Copper toxicity is characterized by a hemolytic crisis which occurs in sheep and goats when the liver copper becomes too high. The liver releases stored copper into the bloodstream, leading to massive hemolysis of red blood cells, anemia, hypoxia, kidney damage or failure, and sometimes death. Copper deficiency is characterized by poor immune function, poor rate of gain and poor reproduction. In some cases, bleaching of the hair coat, especially around the eyes and nose can occur although this is an uncommon occurrence and a lack of bleaching of the coat does not rule out copper deficiency.

Zinc

Zinc is essential for healthy skin and hair, in addition to growth and reproduction. Goats are sensitive to low zinc diets and can develop a condition called "zinc responsive dermatosis" in response. This dermatologic disease is seen more commonly in bucks than does and is characterized by dry, flaky skin predominately over the dorsum as well as dry, brittle hair. As implied, zinc supplementation is curative. Sheep can develop poor wool quality in response to zinc deficiency. The ideal zinc level in the diet should be 30 ppm. Zinc toxicity is uncommon in sheep and goats.

Selenium

Selenium deficiency, or White Muscle Disease (WMD), is a source of serious concern for producers. WMD is characterized by muscle weakness, recumbency and death. It is seen more commonly occurring in young, growing kids and lambs than adults. Selenium deficiency is linked to poor immune function, poor reproduction, and poor rate of gain. Take note that these are the same symptoms listed for copper and zinc deficiency. Blood analysis, liver biopsy, or necropsy is necessary for diagnosing a mineral deficiency or toxicity. Dietary selenium is regulated in most states and is fed at the maximum allowable level of 0.3 ppm. With proper supplementation, selenium deficiency is seldom problematic. Injectable selenium products can assist with short term selenium supplementation but do not provide adequate levels to improve whole body selenium stores. Dietary supplementation of trace elements via feed, either loose salt or combined with the grain supplement, is necessary for animal health.

Macrominerals

Calcium, magnesium, and phosphorus are important macrominerals to monitor. Calcium and phosphorus are both critical for proper bone development in young ruminants. An ideal ratio of Ca:P in the diet is 2 to 1. Grains tend to be higher in phosphorus and alfalfa contributes calcium to the diet. Grasses tend to be low in both calcium and phosphorus. During pregnancy and lactation, managing calcium and phosphorus levels is critical for optimal metabolic health and lactation.

The importance of calcium for close-up does and ewes

Meeting the energy demands of does and ewes during the final month of gestation can be challenging. Pregnancy toxemia and hypocalcemia occur commonly when diets and management do not support the nutritional demands of this period. One of the early symptoms of pregnancy toxemia and quite possibly the most important precursor to more severe clinical signs is clinical hypocalcemia. Does and ewes show difficulty rising, are weak and depressed, and have depressed feed intake. The dietary calcium goal is 1.2-1.4% in close-up does and ewes. Phosphorus should be between 0.5-0.6%. Adequate calcium in the diet along with adequate feed consumption will prevent hypocalcemia. Dietary cation anion difference (DCAD) diets are utilized in bovine dairy production but are less relevant in small ruminants several important reasons. First, does and ewes generally have multiple fetuses which means they have a high calcium requirement in the last month of gestation. We have genetically selected many small ruminant breeds to produce more fetuses per litter. The high total fetal skeletal weight

requires calcium supplementation beyond what the dam's skeleton can mobilize on a DCAD diet, whereas a cow has only one fetus and can utilize skeletal calcium to mineralize her calf's skeleton. Second, many producers do not have adequate information on due dates to ensure that the doe or ewe will only be on the DCAD diet for 3-4 weeks. It is not advisable for these diets to be fed for 2-3 months, especially in a 5-month gestation. Many producers do not have a separate diet for close-up and a far-off animals and some producers combine first parity with older does and ewes. These are not appropriate circumstances in which to implement DCAD diets.

Preventing hypocalcemia starts with appropriate dietary management in the dry period. It requires sustained monitoring during the close-up period in order for does and ewes to maintain adequate feed intake which in turn will prevent the development of pregnancy toxemia.

Conclusions

Small ruminant nutrition is very similar to bovine nutrition; however, behavior and metabolic differences result in several unique qualities which must be accounted for when formulating rations. Higher NSC and protein levels for goats, along with a preference for browsing behavior are important to consider when creating and evaluating goat diets. Although sheep can eat diets similar to those of cattle, they have a higher protein requirement, especially during growth and lactation in addition to a lower copper requirement. The close-up period is the most nutritionally precarious time and meeting the dietary needs of the doe or ewe is critical. With these unique differences in mind, you can support to your clients throughout the production or life stages of your small ruminant patients, herds and flocks.

