Basic small ruminant nutrition

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Abstract

The objective of this presentation is to provide an overview of fundamental nutrient requirements and basic feeding practices for sheep and goats in an effort to improve the practitioner's ability to address related concerns from small ruminant clientele. Many principles of ruminant nutrition as applied to dairy or beef cattle can be extrapolated to sheep and goats, but they should not just be considered "little cows". Feeding behavior of sheep and goats is classified as intermediate browsers compared to the bulk roughage grazing cow. Feed selection and chewing behavior will alter how feeds are processed in the rumen. Additionally, with their smaller size compared to cattle there will be differences in rate of passage influencing rumen dynamics. Equally, sheep and goats are not equivalent, as feeding sheep are more grazers compared to browsing by goats. Sheep and goats also have some significant nutrient requirement differences, especially related to copper, thus products formulated to meet the needs of both species should be scrutinized. The feeding management focus will be on key nutritional principles addressing the role of forage quality on animal health and performance and need for proper mineral and vitamin supplementation. Having an understanding of basic sheep and goat feeding practices can provide an opportunity to offer additional services to new or ongoing small ruminant clients.

Key words: sheep, goats, small ruminants, nutrition

Résumé

L'objectif de cette présentation est de donner un aperçu des besoins nutritionnels fondamentaux et des pratiques d'alimentation de base chez les moutons et les chèvres dans le but de permettre aux praticiens de mieux répondre aux attentes de la clientèle dans ces domaines. Plusieurs principes de nutrition des ruminants, qui s'appliquent aux bovins laitiers et de boucherie, peuvent s'extrapoler aux moutons et aux chèvres bien que ces derniers ne doivent pas être considérés comme des «petites vaches». Le comportement d'alimentation des chèvres et des moutons se classe dans la catégorie des brouteurs intermédiaires alors que les vaches sont plutôt des consommateurs de fourrage grossier. Le choix des aliments et la mastication vont affecter la digestion des aliments dans le rumen. De plus, en raison de leur plus petite taille par rapport aux bovins, il y aura aussi des différences dans le taux de passage qui auront des répercussions pour la dynamique des aliments dans le rumen. Les chèvres et les moutons ne sont pas équivalents : les moutons broutent plus souvent au niveau du sol que les chèvres. Les chèvres et les moutons ont aussi des besoins alimentaires différents surtout en ce qui a trait au cuivre. Il faut donc être à l'affut lorsqu'on achète des produits qui répondent aux besoins des deux espèces. La régie de l'alimentation devrait se concentrer sur des principes de nutrition clés qui relient la qualité des aliments à la santé et la performance des animaux et sur les besoins en supplément de vitamines et de minéraux particuliers. Une bonne connaissance des pratiques d'alimentation de base pour les chèvres et les moutons permettra d'offrir des services additionnels à la clientèle de petits ruminants présente et future.

Introduction

Feed costs can account for 50 to 80% of total sheep and goat production costs.[3] As a result, many producers have become engrossed in reducing costs to feed a ewe or doe/day rather than optimizing their feeding efficiency. The most inexpensive ration is not usually the most production-efficient ration. This statement may sound like a contradiction, but relates to the understanding of how the ewe or doe and associated rumen system interact from a nutrient requirement perspective. A marvelous mutualistic relationship exists between rumen bacteria and host animal allowing consumption of dietary material which would be indigestible to the animal alone, and production of high quality products (e.g., meat, milk and wool) from end products of bacterial fermentation. Producers need to take full advantage of this animal-rumen interrelationship in order to produce desired end products most efficiently.

What separates ruminant from non-ruminant herbivores is their ability to chew their cud. The ability to regurgitate swallowed feed material for remastication provides the rumen microflora greater feed material surface area, thus allowing for greater extent of degradation. Ruminant animals are the most efficient fiber-digesting herbivores. If the rumen system is functioning properly, it can provide a large proportion (>60 to 90%) of needed nutrients to support host animal productive activities. The rumen microbial population converts consumed dietary substances into highly available microbial crude protein (MCP) and volatile fatty acids (VFA) that can be used by the host animal for protein synthesis and energy needs, respectively. In addition to the rumen microbial end products, a proportion of dietary protein, fat, and starch may escape microbial degradation and be directly available for digestion by the host animal. Dietary nutrients escaping rumen degradation are commonly termed bypass protein, fat, or starch. It is the combination of rumen degradation products and dietary bypass nutrients that support all body functions of the host animal. The feeding program becomes most efficient when microbial products from rumen degradation can account for a greater proportion of host animal needs and minimize the need for additional dietary bypass nutrients. To accomplish this, one needs to fully understand the interactions of dietary substrates with rumen environment and impact on fermentation end product production. The objective of this presentation is to provide a fundamental overview of rumen function and dynamics, and integrate these concepts with basic sheep and goat feeding practices for the practitioner having little to no background in feeding small ruminants. Feeding practices will be demonstrated through the use of various case study discussions.

Rumen Microbiology

Over 200 different species of microorganisms have been identified in the rumen. These organisms range from bacteria, the most abundant, to protozoa, fungi, and viruses. The wide variety of bacteria found in the rumen can be loosely grouped into 5 major categories in addition to protozoa. A basic understanding of the nutrient and environmental requirements of these different microbial groups is necessary to fully appreciate how feeding programs may impact rumen health (Table 1). One important concept to glean from this table is the observation that cellulolytic activity (i.e., fiber fermentation) occurs only at higher pH levels.

A healthy rumen is one that has a balanced interaction between all groups of bacteria. In abnormal rumen environments, usually 1 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 starch digesters to overwhelm the rumen environment and eliminate cellulolytic activity. This is the crux of the problem in ruminant animal feeding, providing sufficient grain to support milk production without excessive amounts that can suppress fiber fermentation, milk fat test, and rumen activity. Relative to sheep and goats, they are more efficient chewers and thus cereal grains should not be heavily processed as is the case with cattle. Corn should be just cracked or coarsely ground while oats, barley and wheat should not be processed or only minimally processed. Highly processed grains or pelleted grain products lead to greater challenges with ruminal acidosis in small ruminants. Some processed cereal grains may be fed to high-producing animals with rapid rates of passage through the rumen.

Many rumen microbes are very sensitive to the presence of dietary polyunsaturated fats. Rumen microbes will attempt to reduce polyunsaturated fats by saturating double bonds through a process of biohydrogenation. Recent research has identified *trans*-10, *cis*-12 conjugated linoleic acid (CLA), a product of incomplete microbial biohydrogenation, to be associated with milk fat depression in ruminants.[1,2] The presence of *trans*-10 CLA inhibits or reduces mammary gland *denovo* fatty acid synthesis. The presence of large amounts of polyunsaturated fats in the rumen or under low rumen pH conditions seems to promote the production of *trans*-10 CLA and produce milk fat depression syndrome. This situation would be most significant in a lactating goat feeding program

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

Class of organism	Primary substrate	Specific requirements	Primary end product	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
NSC Bacteria	Starch Sugars	Amino Acids Ammonia	Propionate Lactate Butyrate Ammonia	Acid 5.0-6.6
Secondary feeders	Succinate Lactate Fermentation End products	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

*Adapted from Chase LE, Sniffen CJ, Cornell University.

or in dairy sheep production for yogurt or cheese products. Often producers will want to add dietary fat sources to improve energy balance and promote greater milk production, especially in high-producing dairy goats. One must be careful of the amount of rumen-available fat from polyunsaturated sources (i.e., soybeans, cottonseed, sunflower, canola, and flaxseed) as these will adversely affect rumen fiber digestion and potentially result in milk fat depression.

Rumen fermentation patterns can be manipulated by selective inhibition of specific bacterial populations for positive feeding responses.[14] Ionophore agents (i.e., monensin, lasalocid), beyond their anti-coccidial activity, are examples of such selective inhibition to promote rumen function. Ionophore compounds are essentially antibiotics that inhibit growth of gram-positive bacteria, which includes most fiber-fermenting bacteria. One bacteria, *Streptococcus bovis*, is primarily responsible for ruminal environment changes resulting in lactic acidosis and contributes to bacterial breakdown of dietary protein. It is also very sensitive to ionophores.[13,14] Feeding ionophores results in reduced fiber fermentation, resulting in increased propionate production and reduced protein breakdown in the rumen; all contributing to improved energy and protein availability from the feed. Incidence of ruminal bloat and acidosis is greatly reduced with ionophore use as a direct result of inhibiting the growth of *Strep. bovis*. It must be remembered that lasalocid is only approved for use in sheep, whereas monensin is approved for use in goats.[5,6] Unlike the situation in dairy cattle, both products are only approved in their respective species for use in coccidia prevention in confinement feeding and ***are not approved for use in lactating females***.[5,6]

Nutrient Requirements: Host Animal and Rumen

All living organisms require essential nutrients to support their metabolic processes keeping them alive. General required nutrient classes include water (the most essential), energy, protein, minerals, and vitamins. Minerals can be further subdivided into macrominerals and microminerals based on 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 host animal (e.g., maintenance, growth, lactation, pregnancy) and environmental conditions.[10] Bacteria have similar requirements for maintenance and growth (i.e., reproduction).

Differences between the ruminant animal and microbes are seen in their sources for essential nutrients (Table 2). The host animal derives a majority of its energy and protein from microbial end products or microbes themselves. Bacteria contain between 45 and 65% protein that is of high biologic value and digestibility. Microbial protein production alone can support up to 50 lb (23 kg) of milk production in the dairy cow. Our objective in feeding sheep and goats is to make the bugs grow in the rumen system, thus less additional expensive feedstuffs are needed for the host animal. The first goal of a ruminant 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 economic, productively efficient, and healthy for the animal.

Bacteria require a number of essential nutrients for the synthesis of protein, similar to that of the animal. However, unlike the host animal, 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 animal which needs to be supplied with preformed essential amino acids.

Microbial protein production is a function of rumen-available substrates, primarily carbohydrates and nitrogen.[4,11,15] If any of the required building blocks are in limited supply, MCP production will be determined by the availability of the most limiting substrate. Usually this is energy from carbohydrate fermentation. Energy production (generation of ATP) will be dependent upon the available carbohydrate source and its rate of degradation. This is where forage quality plays an important role. More mature forages (high neutral detergent fiber and acid detergent fiber content) will be more slowly degraded and constrain MCP yield. The rumen ammonia (NH_3) pool 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, cellulolytic bacteria can only use NH_3 as their nitrogen source.[11]

Microbial protein production is more complex than just providing the necessary amounts of dietary substrate. The rumen is a dynamic system that constantly has fermentation end products, liquid, bacteria, and particles being removed via digestion and passage through the rumen as well as new substrate added. So not only do we need to address concepts of total substrate requirements, availability of substrate relative to other substrates needs to be addressed. We must be able to predict rate and extent of carbohydrate and protein degradation taking place in the rumen. This is the critical component of a dynamic modeling system for the rumen, and requires more comprehensive and complex feed analysis

Table 2. Substances that supply essential nutrient needs for the host animal and rumen microbial population.

Nutrient	Ewe/doe	Bacteria
Energy	VFAs, dietary bypass glucose, fat	Complex carbohydrates sugars, starches, amino acids
Protein	Microbial protein, undegradable dietary protein	Ammonia, amino acids, peptides
Minerals	Dietary	Dietary
Vitamins	Dietary and bacterial	Dietary or synthesized

procedures. These dynamic programs are now being applied to small ruminant feeding practices.

Although the rumen system is a great benefit to the animal in providing a high quality protein source and available energy from mostly indigestible feed sources, there are some negative aspects of the rumen system. The primary concerns with the rumen are relative to vitamin and mineral nutrition. The fat-soluble vitamins, primarily A and E, are either degraded or complexed in the rumen, making them unavailable to the host animal. This results in higher vitamin requirements for ruminants compared to non-ruminant animals. Feeding of stored forages results in low dietary vitamin content, thus requiring appropriate supplementation. Additionally, a number of minerals, most notably copper and selenium, are altered in the rumen environment and made unavailable to the host animal.

Small Ruminant Feeding Program Essentials

There are many different methods in which sheep and goats can be fed appropriately. Much of the decision process in designing a feeding program will revolve around the source and type of forage to be fed. Forage should be the predominant component of the diet, whether hay, silage, or pasture. Browse can also supply a significant portion of dietary forage, especially for goats as their feeding behavior is selective browsing. Beyond the dietary forage component, cereal grains, by-products feeds, and plant protein sources are used to provide additional energy and protein to the diet above what is available in the forage. The amount of energy and protein supplements in the diet will depend upon forage quality and requirements for the given physiologic state. Additional mineral and vitamin supplements are provided to complement forage mineral content in meeting the animal's requirements. A generalized summary of feeding plans for sheep and goats in various physiologic states is provided in the Appendix.[1]

Water

Water is the most essential of the nutrients, yet it often is the most neglected. Requirements are defined relative to dry matter intake and adjusted for environmental conditions. Typical maintenance water intake is 1 to 1.8 quarts/lb (2.1 to 3.7 L/kg) of dry matter intake in a neutral environment.[10] Water intake will increase with pregnancy, lactation, and growth, and for any physiologic state will be greater in heat stress conditions. Beyond availability of water, a significant issue to address is water quality and the animal's willingness to consume the water. Issues such as pH (6 to 9 pH units is optimum), total dissolved solvents (TDS, < 1000 ppm desirable), mineral content, and microbiologic contamination are all issues to address.

Dissolved mineral in water can also be a concern relative to animal performance and health. High iron (>0.3 ppm) can reduce water palatability, which may be a contributing factor to low intake or urolithiasis in feedlot lambs and kids or rams and bucks. High molybdenum (>0.5 ppm) or sulfates (>500 ppm) could contribute to the production of thiomolybdates in the rumen and chelate copper, reducing dietary availability. Identify an accredited water testing laboratory and have the water tested at least once as part of your feeding program evaluation to confirm quality or potential issues.

Adequate Forage Feeding

Though fiber is not an essential nutrient from the perspective of the ewe or doe, it is an essential dietary component in feeding the rumen microbes and maintaining a cost-efficient diet. Forage quality has a tremendous impact on overall dietary balance and animal performance. Within the 2 agronomically significant forage sources (legumes and

Table 3. Typical test value of alfalfa and grass hays harvested at various stages of plant maturity (all values on dry matter basis).

Hay type and maturity stage	CP % DM	ADF % DM	NDF % DM	ME Mcal/lb	TDN % DM
Alfalfa					
Pre-bloom	> 19	< 31	< 40	1.03 - 1.13	63 - 66
Early bloom	17-19	30-35	40-46	0.98 - 1.02	60 - 62
Mid bloom	13-16	36-41	46-51	0.92 - 0.97	56 - 59
Late bloom	< 13	> 41	> 51	< 0.90	< 55
Grass					
Pre-head	> 18	< 33	< 55	0.98 - 1.07	60 - 65
Early head	13-18	34-38	55-60	0.85 - 0.91	52 - 56
Head	8-12	39-41	61-65	0.75 - 0.84	46 - 51
Post-head	< 8	> 41	> 65	< 0.75	< 46

grasses), fiber and lignin content increase while protein and energy content decline with maturity (Table 3). Due to anatomic differences between legumes and grasses, legumes are less adversely affected by maturity, though the legume stem becomes nearly indigestible. Plant growth is highly controlled by environmental light and temperature, which accounts for differences in stage of maturity at similar physiologic states during the growing season (e.g., different cuttings).

A key factor of plant maturity is the role that neutral detergent fiber (NDF) plays in intake capacity. The ruminant animal masticates forage fiber to reduce particle size and facilitates rumen microbial degradation prior to dietary fiber being passed out of the rumen. The capacity of the rumen microbial environment directs intake capacity unless the rumen filtering system is perturbed. As a consequence, intake capacity can be predicted from forage NDF content to some degree. Work by Mertens in cattle and sheep has shown an optimum total NDF intake capacity of 1.2% of body weight.[8,9] Forage NDF should account for 80-90% of total NDF, thus dietary NDF from forage should range from 1.0 to 1.1% of body weight (BW). Intake data from cattle and sheep show NDF intake capacity to be lower in late pregnant and early lactating animals.[9,12] Late pregnant sheep fed silage exclusively showed a decline in NDF intake capacity as a result of increasing gestation (15 to 20 weeks) and number of fetuses.[12] Intake of NDF declined from 0.8 to 0.6 % BW by gestation week and litter size, with ewes pregnant with triplets having an NDF intake of 0.5% BW by the end of gestation.[12] This relationship between NDF intake capacity and forage quality explains the limitations of poor forage quality in supporting highly productive or late pregnant animals (Table 4). Goats may be less sensitive to forage NDF issues due to their selective feeding behavior, though feeding of mature grass hay (NDF > 65% DM) can still be a problem as the "leaf and stem" are intertwined and equally affected by lignification in grasses. This may suggest the feeding of alfalfa hay in later pregnancy allowing for some "selective feeding behavior" may be of benefit in late pregnant sheep and goats as well as providing greater dietary calcium to support fetal development.

Table 4. Predicted dry matter intake (DMI) as a percent of body weight related to neutral detergent fiber (NDF) intake capacity.

Forage NDF %	DMI	NDF capacity (% of body weight)			
		1.2	1.0	0.8	0.6
38	Intake as a % of body weight	3.16	2.63	2.11	1.58
42		2.86	2.38	1.90	1.43
44		2.61	2.27	1.74	1.36
46		2.73	2.17	1.82	1.30
50		2.40	2.00	1.60	1.20
54		2.22	1.85	1.48	1.11
58		2.07	1.72	1.38	1.03
62		1.94	1.61	1.29	0.97
66		1.82	1.52	1.21	0.91

Energy

Energy to support physiologic functions is derived from carbohydrate, protein, and fat oxidation. Ideally, most energy should be derived from VFA generated by rumen microbial fermentation of dietary fiber and more readily available carbohydrates. Again, forage quality will determine how much energy will be available via fermentation. Additional energy from starch (e.g., cereal grains) or readily fermentable fiber (e.g., soyhulls, wheat bran or midds, beet pulp) supplements can be provided to increase dietary energy density. Typically 1 to 2 lb (450 to 900 g) of cereal grains would be needed to support late pregnancy with moderate quality forage. For lactating animals, 1 lb (450 g) of grain is needed for each 2 to 3 lb (0.9 to 1.4 kg) of milk yield.[1,10]

A key problem in providing high-starch feed supplements is the adverse effects of lactate production on the rumen environment. This can be somewhat altered by use of rumen buffers, particle size of the starch source (larger size slows degradation), and starch source (wheat and oat starch is highly available compared to corn). The amount of starch necessary will depend upon forage quality. Potentially some fat can be provided in the diet, but vegetable fats should be limited (<3% DM). If starch sources are primarily being used to supplement needed energy, minimize the fermentable carbohydrate load per meal by feeding lesser amounts but more often (3 vs 2 meals).

Protein

Protein is the single most expensive component of the total diet. Excess dietary protein becomes an energy drain on the animal as it needs to metabolize and excrete the excess nitrogen, a potential environmental issue. The dietary focus is to provide sufficient dietary nitrogen sources to meet microbial needs and maximize MCP yield. To ensure this, at least 7 to 9% rumen degradable protein should be fed. Approximately 30 to 40% of rumen-degradable protein can be soluble to provide readily available nitrogen to the fiber-fermenting microbes. Use of expensive bypass protein sources is only necessary in highly productive animals (early lactation, parlor milking, and late pregnancy). With many brewer's or distiller's grains becoming more readily available for lower cost, it is often enticing to feed at higher rates to high producing animals. One needs to be careful not to "starve" the rumen microbial fauna by feeding large amounts of these bypass protein sources. Formulating sheep and goat rations for protein fractions is only now becoming more commonplace with the recent NRC publication.[10]

Minerals

Forages will provide much of the macrominerals, though legumes will provide much more calcium compared to grasses. Forages are generally low in many of the microminerals and will need to be supplied via a mineral supplement, either fed free choice or incorporated into a complete supplement. The primary difference in mineral programs for sheep and goats is relative to copper. Goats have a higher copper requirement and are less sensitive to toxicity issues as compared to sheep.[10] There are some nuances relative to other mineral requirements between sheep and goats.

In evaluating a feeding program, 1 of the first considerations relative to minerals is to review the macromineral status of the forage. In many situations the phosphorus content is much higher, making a very narrow calcium-to-phosphorus ratio. This could lead to bone development issues (rickets, osteomalacia), hypocalcemia in late pregnant ewes and does, or increase the risk for urolithiasis in males. Most small ruminant owners purchase their forage and will have highly variable mineral content, depending upon stage of maturity and fertilization practices of the grower. Forage potassium and magnesium should be reviewed as high potassium intake will interfere with magnesium absorption. High potassium can also predispose to hypocalcemia and increase the risk for urolithiasis by alkalizing urine. A preferred dietary ratio of potassium to magnesium of 3.8 to 4:1 is suggested, and may require some additional magnesium in the mineral supplement.

Trace mineral nutrition is to be considered as a local geographic issue. There is variability across the US relative to trace mineral status, especially for copper and selenium. Zinc is generally deficient in most forages. The key issue for small ruminants is to assess copper availability relative to other dietary inhibitors (iron, sulfur and molybdenum). Also remember excessive zinc will also inhibit copper availability. The distribution of molybdenum seemingly is sporadic, and high concentrations may be found in forages from 1 farm and not another within a given locality. Causes of high molybdenum in forage may be due to local mining activity, fertilization with biosolids, and industrial pollution. Iodine may also be deficient, especially around the Great Lakes region. Boer goat phenotypes seem to have a higher iodine requirement.

Providing a trace mineral supplement is best achieved by incorporating the trace mineral premix into a concentrate supplement or within a commercial supplement. In many situations, some grain supplement is not fed and a free-choice mineral is provided to meet the trace mineral needs. It must be remembered that sheep and goats do not have specific appetites for the various minerals and they are not capable of assessing their mineral needs. Trace minerals are provided as a food source using salt as the delivery vehicle. Animals have an appetite for sodium and will crave a salt source. However, they cannot distinguish between a white salt source (no trace minerals) and a trace mineral source, thus only 1 source of salt should be provided. For free-choice mineral salt containing between 24 and 33% salt, expected average intake is between 0.25 to 0.33 oz/day (7.1 to 9.4 g/day). This intake will be highly variable across animals depending upon many factors. At this rate of expected intake, a free-choice trace mineral salt product may contain a maximum of 90 ppm selenium to deliver 0.7 mg selenium.[7] Many products will have a lesser selenium concentration and a higher expected intake, which may not be what is observed. Relative to copper, typically a sheep trace mineral salt will contain 30 ppm copper or less. With a higher copper requirement for goats, a free-choice mineral product should contain 1000 ppm or more depending upon the level of inhibitors in the diet.

Vitamins

It is believed that the B-complex vitamins are not necessary to supplement in the ruminant diet due to bacterial synthesis. However, a sick animal's reduced feed intake or abnormal rumen function may not be generating sufficient B-vitamins, and additional supplementation may be of benefit.

The fat-soluble vitamins A, D, and E should be considered for supplementation in the diet, especially when stored forages are being fed over the winter feeding period. Sheep and goats consuming fresh pasture and exposed to sunshine will receive sufficient fat-soluble vitamins without additional supplementation. When stored forages (silage or hay) are being fed, then natural sources of vitamins A and E will no longer be present in sufficient quantities to support normal functions, and risk for deficiency symptoms is increased. All fat-soluble vitamins can be readily provided in either a free-choice mineral product (limited shelf life for vitamins) or a complete supplement. A wide range of products are available with an equally wide range in vitamin content. Individual products will need to be evaluated relative to their vitamin concentration and intended intake rate to determine if they will provide sufficient level of vitamin supplementation.

Conclusions

There are many equally satisfactory methods by which sheep and goats in various physiologic states can be fed to meet their nutrient needs. In feeding the ruminant animal one must first consider how dietary ingredients are providing for the needs of the rumen microbial populations, namely sufficient fiber, energy, and protein resources to maximize microbial protein production. To this end, most diets for sheep and goats should provide approximately 1% NDF from forage sources in forming the foundation of the diet. Additional energy, protein, mineral, and vitamin supplements can be provided to balance out the required nutrients for the animal. The most recent National Research Council publication provides the best nutritional guidelines for feeding small ruminants.

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Appendix 1. Suggested feeding plans and dietary guidelines for sheep and goats based on physiologic state.

Group	Feeding plan	Dietary guidelines*
Lactating females	Highest nutrient requirements, feed best-quality forages, with energy/protein supplements	60 to 70% TDN, 12 to 14% Crude protein, 0.45 to 0.62% Ca, 0.32 to 0.45% P,**
Weanlings up to 1.5 years	Highest nutrient requirements, feed best-quality forages, with energy/protein supplements	55 to 65% TDN, 14 to 16% Crude protein, 0.53 to 0.73% Ca, 0.27 to 0.38% P, **
Pregnant females 1 to 3.5 months	Low requirements, but ensure no loss of body condition, adequate protein, minerals, and vitamins	50 to 55% TDN, 8 to 10% Crude protein, 0.2 to 0.24% Ca, 0.12 to 0.2% P
Pregnant females 3.5 to 5 months	Moderate to high forage quality with supplement for additional mineral and vitamin needs	55 to 70% TDN, 10 to 14% Crude protein, 0.45 to 0.56% Ca, 0.28 to 0.33% P, **,†
Breeding females	Low to moderate; ensure do not become fat or lose condition	50 to 55% TDN, 7 to 9% Crude protein, 0.2 to 0.24% Ca, 0.12 to 0.2% P
Males >1 year	Low requirements unless working, then adjust accordingly, low-to-moderate quality forage	55 to 60% TDN, 8 to 10% Crude protein, 0.3 to 0.48% Ca, 0.21 to 0.28% P,**

*Ensure adequate available water and free choice salt. White salt should be used when trace minerals are included in a supplement. Otherwise trace mineral salt should be available.
**These feeding groups require higher amounts of trace minerals and vitamins, preferably delivered by a supplement.
†Dietary energy and crude protein content may need to be increased further in late pregnancy if dry matter intake drops below 1.75% of body weight.