Dairy Goat Nutrition: Feeding for Two

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

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Part 2- Forage

Feed costs account for more than 60% of dairy or meat goat production costs. As a result, many producers have become engrossed in reducing the cost to feed a goat per day rather than optimizing their feeding efficiency. The cheapest ration is not usually the most production-efficient ration. This statement may sound like a contradiction, but relates to the understanding of how the goat and its rumen interact from a nutrient requirement perspective. In Part 1 of this article (HoofPrint Winter 2017), the exquisite interrelationship between the goat and the microbial population in its rumen was described laying the foundation for understanding appropriate feeding practices. This discussion focused on the importance of forage feeding to support microbial fermentation, rumen health and productive efficiency. The objective of this article is to better define forage quality through sensory and feed testing methods in order to provide the goat producers with the information necessary to better evaluate the use of forages in their feeding program.

Understanding Forage Quality

From the Dairy Goat Nutrition: Feeding For Two (How to properly feed the goat and her rumen) Part 1 in the Winter 2017 HoofPrint, we discussed how the goat digestive tract is designed to utilize forage materials. Goats require a wide variety of nutrients, including energy, protein, minerals and vitamins, to support bodily functions. Feeds are not equal in their ability to support animal functions of maintenance, growth, reproduction and lactation. Feed nutritive value is a function of the availability of energy and essential nutrients in support of animal performance. Three components of nutritive value are:

1. Digestibility - ability of the animal to break down the feed in the digestive tract;
2. Intake - how much of the feed the animal is able to consume, limited by fiber content (measured as neutral detergent fiber [NDF]) as well as other factors; and
3. Energetic efficiency - ability of the animal to obtain energy from the feed that can be used for production and maintenance purposes.

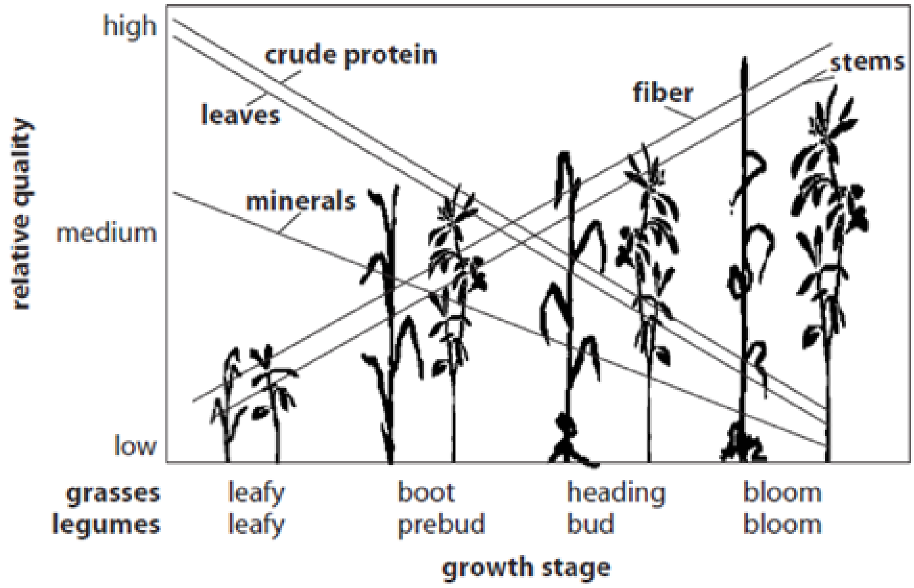

Figure 1**. When grasses or legumes grow from leafy to bloom growth stages, protein and mineral contents decline dramatically with leafiness. Concurrently, stems and cell wall materials increase rapidly as canopies grow to a mature bloom stage.**

How well a particular forage meets these nutrient needs will determine the amount and composition of supplements, if necessary, to meet the goat's nutrient needs. High quality forages will require minimal supplementation compared to poor quality forages.

Forages, whether hay, silage, or pasture, have always provided the foundation of the goat ration. Most forages fed to goats are either grasses or legumes, but given their browsing preferences they may also consume a wide range of plant materials. Forage quality, irrespective of source, varies tremendously and will tremendously impact the feeding program. A multitude of factors can influence forage quality including: plant species, plant maturity, environmental conditions, fertilization, water availability, time of cutting, and storage practices. As a result, hay harvested from the same farm and field can vary within a year and among years. Also, it cannot be assumed that hay bought from the same person year after year will be the same quality each time! Unfortunately, hay quality does not necessarily direct the price. Often good and poor quality hays are sold for the same price, especially in years where hay production was limited. Your feed dollar is best spent on good quality hay. Factors that affect forage or feed ingredient quality include the following:

1. Plant species - legume hay generally higher in protein (16-20%), energy (NE_l = .63 Mcal/lb) and minerals (1-2% Ca) than grass hays (8-13% protein, NE_l = .49 Mcal/lb, .3-.75% Ca)
   a. Leaf-to-Stem Ratio - since leaves contain more energy and protein than stems, leafy hay of any type is desired.
   b. Reserve substances - seeds and plant starches, highly available and digestible
   c. Resistant substances - cell wall material and other compounds (lignin, tannins, cutins) that help the plant survive in the environment; poorly digested and reduce feed quality
   d. Nutrient content interrelationships - ratios between energy, protein, fiber in the feed relative to specific nutrient requirements.
2. Stages of maturity or date of cutting. Plant maturity is the single most important factor that determines

forage quality. The later the date of harvest, the lower the protein and energy content of both legume and grass hays, but the higher the dry matter content (Figure 1). Best time to harvest varies, but end of budding to early bloom stage is a good rule for most species.

3. Environmental Effects - environmental temperature and daylight are the two most important factors influencing plant growth. Sunlight increases digestible carbohydrate content of the plant, while temperature increases plant cell wall formation and lignification. The interaction between temperature and daylight can explain the differences from cutting to cutting.

4. Methods of Processing - a variety of methods can be used to increase the availability and digestibility of a feed source. Fiber sources are usually ground and pelleted to increase intake. Cereal grains may be ground, flaked, popped, or steam-flaked to increase the digestibility of the starch in the grain.

5. Storage practices - exposure of feed ingredients, especially forages, to moisture and oxidation (light, minerals) will result in a variable rate (3 to 40%) of nutrient loss. Most of these losses are highly available carbohydrates resulting in dramatic decreases in feed digestibility.

Forages are necessary to provide sufficient effective fiber to maintain rumen function and health. Fiber becomes a serious limitation to meeting energy needs with ever increasing levels of milk production. Feeding more grain to compensate for poor quality forages is not a feasible solution to maintain rumen or animal health. How do we determine quality of forage? This can be accomplished primarily through chemical analysis of the forage and sensory inspection. Sensory inspection can be helpful in distinguishing between poor and high quality forages, but, it cannot predict nutrient content. Chemical or nutrient analysis is the best method to estimate forage quality.

Table 1. Sensory evaluation in assessing forage quality.

Sensory Evaluation	Description/Comments
Visual Stage of maturity	Look for the presence of seed heads (grass forages) or flowers or seed pods (legumes), indicating more mature forages
Leaf to Stem ratio	Look at forage and determine whether stems or leaves are more obvious; high-quality legume forages will have a high proportion of leaves; stems will be less obvious
Color	Color is not a good indicator of nutrient content, but bright green color suggests minimal oxidation; yellow hay indicates oxidation and bleaching from sun; hay will have lower vitamins A and E content
Foreign Objects	Look for presence and amount of inanimate objects (twine, wire, cans, etc.), weeds, mold, or poisonous plants
Touch	Feel stiffness or coarseness of leaves and stems; see if alfalfa stems wrap around your finger without breaking; good-quality hay will feel soft and have fine, pliable stems
Smell	Good quality hay will have a fresh mowed grass odor; no musty or moldy odors; carmel or tobacco smell to hay indicates heat damage; silage should have slight pleasant fermented smell; vinegar, sweet, alcohol, tobacco, or rancid milk odors to silage indicate an abnormal fermentation has taken place and further diagnostic testing should be completed.

Sensory Evaluation of Forages

Although sensory evaluation of any given forage will not provide guidance as to the actual nutrient content of the forage, a careful evaluation process can provide some insights as to expectations for maturity, which will reflect nutrient content and potential risks (foreign objects, noxious weeds) (Table 1). It is recommended you visually inspect the forage for presence of mold and, if present, refrain from smelling as you might be inhaling mold spores that could initiate an allergic response. Smell of the forage is an important criterion, but one needs to be cautious in using this sense.

1. Stage of Maturity refers to the growth stage of the plant at the time of harvesting. As with all living things, specific changes occur with aging. As a plant becomes more mature, the cell wall portion increases (Table 2). All other nutrients will decrease with the increase in cell wall. Many nutrients can become unavailable as a result of being bound to the cell wall. More mature plants will have larger and thicker stems and either seed heads or blooms.

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Table 2. Typical test value of temperate and subtropical alfalfa and grass hays harvested at various stages of plant maturity (all values on dry matter basis).[1,2]

Hay Type and Maturity Stage	CP % DM	ADF % DM	NDF % DM	ME Mcal/lb	TDN % DM
Temperate Forages					
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 **,+					
Prehead	> 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
Subtropical Forages					
Alfalfa*					
Pre-bloom	25-30	30-32	33-41	1.03 - 1.13	63 - 65
Early bloom	19-27	34-37	40-47	0.95 - 1.02	58 - 62
Mid bloom	18-23	35-39	46-51	0.90 - 0.93	55 - 57
Late bloom	17-18	>41	>51	< 0.89	< 54
Grass**,++					
Prehead	18-19	32-33	64-69	0.84 - 0.98	51 - 60
Early head	8-18	34-40	64-79	0.74 - 0.82	45 - 50
Head	6-11	39-43	70-80	0.66 - 0.72	40 - 44
Post-head	4-9	39-47	71-81	< 0.66	< 40

[1]Adapted from Van Soest PJ: *Nutritional Ecology of the Ruminant*, ed 2, Ithaca, 1994, Cornell University Press and National Research Council, Subcommitte on Feed Composition, Committee on Animal Nutrition: *United States-Canadian Tables of Feed Composition: Nutritional Data for United States and Canadian Feeds*, rev ed 3, Washington, DC, 1982, National Academy Press.

[2]Abbreviations: CP = crude protein; ADF = acid detergent fiber; NDF = neutral detergent fiber; ME = Metabolizable energy; TDN = total digestible nutrients; DM = dry matter.

*Alfalfa growth stages: pre-bloom = bud to first flower; early bloom = up to 1/10 of plants in bloom; mid bloom = 1/10 to 2/3 of plants in bloom; late bloom = >66% in bloom.

**Grass growth stages: prehead = late vegetative to early boot stage; early head = emergence of seed heads (inflorescence); head = further emergence of seed heads, seeds become well formed; post-head = seeds fully matured and released.

+Summary analysis from orchardgrass, reed canarygrass, smooth bromegrass, and tall fescue.

++Summary analysis from Bahiagrass, Pangola, and Bermudagrass at 2-3 (Prehead), 4-6 (Early head), 6-8 (Head) and 10 (Post-head) weeks of growth.

2. Leafiness is an important factor in evaluating hay since most of the digestible nutrients, especially protein, reside in the leaf. As the plant matures the leaf-to-stem ratio will decline. If the plant is not cured and handled properly many leaves will be lost due to shatter, especially for alfalfa hays.

3. Color of forage can indicate when the plant was cut and how well it was cured and stored. Bright green color indicates high vitamin A content and generally high quality. Yellowing color to the hay may indicate excessive sun curing, overly mature forage or both. Brown to black discoloration usually indicates heating from fermentation and moisture damage. These forages have the highest potential for molding and are unacceptable feeds. Silages may be a yellow color or greenish color as a result of abnormal fermentations.

4. Odor of high quality hay should be similar to newly-mown grass. Hay should not have a musty, mildew or rotten smell. Be cautious in smelling forages for risk of mold spores. Silages that smell like vinegar, ethanol, or rancid butter all have abnormal fermentations, which can result in depressed feed intake. Heat-damaged feeds will smell like tobacco, caramelized, or burned.

5. Foreign Material is anything which does not belong in hay. Harmless foreign material would include certain weeds, other plants, sticks or dirt. Other materials that could harm the goat can also be found in forages. These materials may include poisonous plants, awns, metal objects, insects and molds. High quality forage should be free of foreign material.

Feed Nutrient Analysis

A forage, or any other feed, can be analyzed for its nutrient content by two methods: wet chemistry or near infrared spectroscopy (NIR). A wide variety of tests can be completed by most forage testing service labs (Figure 2). The most common tests run are listed and detailed below:

1. Dry Matter Content is determined by heating a weighed sample of the feed in a drying oven until a constant weight and is expressed as a percentage of weight of the wet sample. Example: a forage which contains 10% water has a dry matter content of 90%. Hay and other dried feeds should contain less than 15% moisture, otherwise they are prone to molding. Silages will vary from 70% to 50% moisture. Pasture may contain anywhere from <15% to 25% dry matter.

2. Crude protein is determined by measuring the nitrogen content of a sample of the feed and multiplying by 6.25 (assumes all nitrogen in the sample is protein nitrogen and that protein is approximately 16% nitrogen). Protein content of a forage will depend upon

Figure 2. **Comparison of essential nutrients, feed chemical composition, and analytical testing procedures.**

<table>
<tr><th colspan="2">Essential Nutrients</th><th>Chemical Components</th><th colspan="2">Analytical Procedures</th></tr>
<tr><td colspan="2">Fatty acids, fat-soluble vitamins</td><td>Lipids, pigments, sterols</td><td colspan="2">Ether Extract</td></tr>
<tr><td colspan="2">Protein, amino acids</td><td>Nitrogen-containing compounds - protein, nonprotein nitrogen</td><td colspan="2">Kjeldahl Procedure (Crude Protein)</td></tr>
<tr><td colspan="2">Inorganic minerals</td><td>Ash</td><td colspan="2">Ashing (complete combustion)</td></tr>
<tr><td rowspan="6">Carbohydrates</td><td rowspan="2">Glucose</td><td>Sugars</td><td rowspan="2">Nonstructural Carbohydrates‡</td><td rowspan="3">Nonfiber Carbohydrates+</td></tr>
<tr><td>Starches</td></tr>
<tr><td rowspan="4">Dietary fiber</td><td>Soluble fiber</td><td></td></tr>
<tr><td>Hemicellulose</td><td></td><td rowspan="3">Neutral Detergent Fiber</td></tr>
<tr><td>Cellulose</td><td rowspan="2">Acid Detergent Fiber</td></tr>
<tr><td>Lignin*</td></tr>
</table>

*Lignin is not truly a carbohydrate compound but is so intimately associated with cell wall carbohydrates that it is often included as such.
‡Enyzmatic methods used to determine sugar and starch content.
+Determined by difference (100 - CP - EE - NDF - Ash).

the plant species. Protein content from lowest to highest for common forages will be: corn silage (7-9%), grass (8-14%), and alfalfa (15-22%). A grass forage containing less than 8% crude protein is not desired for a feeding program.

3. Fiber analysis is a measure of the plant cell wall and other less digestible or fermentable components of the plant. The original measure of fiber is Crude Fiber (CF). However, crude fiber does not define the total cell wall fraction (indigestible or slowly digestible material) of feedstuffs very well. This results in overestimation of the energy values for forages in comparison to concentrates. As a result, a newer procedure to determine cell wall content was developed.
   a. Neutral Detergent Fiber (NDF) contains hemicellulose, cellulose and lignin, which better represents the total cell wall portion of the plant. NDF content of a plant has been associated with intake. The higher the NDF the more mature and lower quality the plant (Table 1).
   b. Acid Detergent Fiber (ADF) contains cellulose and lignin. The difference between CF and ADF is that the ADF fraction more closely estimates the poorly digestible carbohydrate fraction than does CF, which excludes some poorly digestible components. Low quality forages have higher ADF values (Table 1).

3. Minerals - both macromineral (e.g., calcium, phosphorus, magnesium, potassium, sodium and sulfur) and micromineral (e.g., iron, copper, zinc,

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manganese and molybdenum) content can be determined. Mineral analysis is not always done since it is the most expensive test. Mineral content of forages will depend upon plant species, soil conditions and fertilization practices and are very variable. Interpretation of forage mineral is provided in Table 3.

Table 3. Interpretation of forage mineral content

Macromineral	Deficient	Marginal	Adequate	Excessive
Calcium, %	< 0.2	0.2 – 0.3	0.35 – 0.8	> 1.5
Phosphorus, %	< 0.1	0.1 – 0.18	0.2 – 0.4	> 0.5
Magnesium, %	< 0.05	0.05 – 0.1	0.1 – 0.25	> 0.4
Potassium, %	< 0.4	0.4 – 0.6	0.6 – 0.8	> 1.5
Sulfur, %	< 0.10	0.1 – 0.14	0.15 – 0.20	> 0.35
Micromineral	**Deficient**	**Marginal**	**Adequate**	**Excessive**
Copper, mg/kg	< 4	4 – 7	8 – 12	> 20
Iron, mg/kg	< 50		50 – 200	> 400
Manganese, mg/kg	< 20	20 – 39.9	≥ 40	> 300
Molybdenum, mg/kg			< 1.0	> 3.0
Selenium, mg/kg	< 0.1	0.1 – 0.2	> 0.2	> 5.0
Zinc, mg/kg	< 20	20 – 29.9	≥ 30	
Cu:Mo ratio	< 4.0:1	4.0 – 4.5:1	> 4.5 – 6:1	> 16:1

Energy is derived from carbohydrate, fat and protein. Energy content of a feed (i.e., digestible energy, total digestible nutrients [TDN]) is not directly measured like other nutrients but, derived through regression equations. ADF and CP values are used to predict energy value. Most labs report energy values based on cattle equations, which are reasonably close estimates for goats.

The cost of nutrient analysis is variable with a range from $15 for limited information up to $95 for a more extensive report. As with hay prices, a high cost does not necessarily mean a high quality report. Lower cost packages typically use NIR analyses, which are limited in accurately determining minerals, compared to wet chemistry. However, wet chemistry is usually more expensive. Many forage testing laboratories are providing mixed analytical testing using both NIR and wet chemistry on minerals to provide a lower cost, comprehensive forage analysis. One needs to contact a number of labs and ask questions concerning methods used, quality control validation, retesting procedures and costs. The National Forage Testing Association (www.foragetesting.org) provides a listing of certified laboratories by state and information on proper forage sampling. With an analysis of the feed, one can better address the nutritional needs of the rumen and goat to minimize health problems and maximize milk production.

In this second article we focused on improving your ability to recognize forage quality to better provide more nutrients to goats, thus minimizing the need for additional supplements. Mother Nature has developed an exquisitely orchestrated interrelationship between goat and rumen bacteria. This relationship allows the goat to utilize feed materials that could not have used without the aid of the rumen bacteria. In our agricultural production systems we should be taking full advantage of this system rather than trying to work against it or attempt to ignore the rumen and its function. Our feeding programs should be formulated to address daily nutrient needs for both goat and rumen in order to maximize milk or meat yield for minimal total feed costs and maintain animal health and longevity, thus making milk or meat production more efficient. Quality forage is the cornerstone of a goat feeding program. Through both sensory and feed testing assessments informed decisions can be made on providing the most appropriate forage to a specific feeding program.

Dr. Van Saun *is a professor and extension veterinarian with Pennsylvania State University. He has a clinical practice background and completed graduate work in ruminant nutrition at Cornell University. He lectures nationally and internationally on nutrition and health topics for cattle and small ruminant animals.*