Determining Forage Quality: Understanding Feed Analysis

Robert J. Van Saun, DVM, MS, PhD
Department of Veterinary and Biomedical Sciences
Penn State University

A goal for any feeding program is to achieve an appropriate balance among available feed ingredients where total ration nutrient composition meets daily nutritional needs of the animal or animals. To accomplish such a feat on a day-to-day basis, one needs to have some information as to the nutrient content of feed ingredients. Tremendous variation exists in nutrient composition between different feeds. Even within a feed ingredient, there is potential for significant variation in composition. This is especially true for forages. Forages harvested off the same field within the same year can have very different composition as influenced by environmental conditions and cutting time. In a previous column, the concept of forage quality was defined and its affect on a feeding program described. Low quality forages have less available nutrients, thus require larger amounts of supplements to be added. Unsupplemented low quality forages may predispose pregnant or lactating females to hepatic lipidosis or slow rate of gain in growing animals. Supplemental feeds are often cereal grain based and their over consumption may increase risk of digestive upsets and acidosis. In this column I will address forage testing practices as they relate to evaluating quality of your forage.

A variety of biologic, chemical, enzymatic, and other sophisticated analytical methods are used to evaluate nutrient content and availability of feeds. Chemical methods can directly measure quantities of compounds associated with an essential nutrient; however, they tell us nothing about availability. Biologic, enzymatic, and other sophisticated methods provide a more nutritional perspective to feed analysis; thus helping us to better understand just how the animal will interact with its feed. More information is needed to routinely apply these analytical techniques to feeding camelids. The most practical approach to feed analysis is one of chemical composition-- direct determinations of moisture, ether extract (fat), ash (mineral), nitrogen (crude protein), and fiber fractions. A comparison between required essential nutrients, feed chemical composition, and analytic methods used in feed analysis is summarized in **Figure 1**. Although wet chemistry analysis is considered the "gold standard" for feed testing, simpler and less expensive methods with shorter turnover time were needed. Newer technologic advances have brought a rapid, lower cost analytical technique termed near infrared reflectance (NIR) spectroscopy. In general, NIR analysis has high accuracy in measuring crude protein and fiber fractions compared to wet chemistry, but is less accurate in measuring feed mineral content. Many certified feed analysis laboratories are capable of completing wet chemistry, NIR analyses, or both. Certified feed analysis laboratories around the world can be found through the National Forage Testing Association website (www.foragetesting.org). This site also provides information on how to take a representative feed sample for analysis. The basic tests to evaluate forage quality described below can be determined by most laboratories at a cost between $12 and $30

Van Saun, R.J. Determining forage quality: Understanding feed analysis. Lamalink.com August, 2006;3(8):18-19,22,24, 25-26.

depending upon methodology used (wet chemistry vs. NIR) and number of tests performed.

Determinants of Forage Quality

As previously described, forage quality reflects the ability of a given forage to meet the nutrient needs of the consuming animal. Forage fiber content is the primary detractor to high intake and nutrient availability. Relative to assessing forage quality, fiber tests are our single best method, though additional tests for protein and moisture can help to further characterize the forage. The following are brief descriptions of forage analysis tests and their interpretation relative to forage quality.

Dry Matter (DM)

Dry matter is defined as the non-moisture portion of a feed ingredient or diet. The sum of moisture and dry matter content of a feed on a percent of total will always equal 100. Dry matter contains the essential nutrients within a given feed ingredient or forage. Feeds, and thereby diets, vary widely in their moisture content. Pastures and liquid feeds have moisture content between 75 and 90% (10-25% DM). Dried feeds usually have less than 15% moisture (>85% DM). Moisture or dry matter content of a feed is determined by heating a weighed sample of feed in a convection drying oven until a constant weight is reached (24-48 hours). Dry weight is expressed as a ratio to original sample weight (moisture + DM) or converted to a percent. For example, a feed sample weighs 150 g wet and 50 g dry. The DM ratio would be 0.33 (50/150) and percent DM 33.3% (50/150 x 100). The moisture content of this feed would be 66.7% (100-33.3 or [150-50]/150 x 100).

Why is knowing moisture content important? One important aspect is our ability to compare nutrient content of different feeds on an equal basis. Nutrient content of a feed can be determined on an "As Fed" (AF; moisture included), or dry matter (moisture excluded) basis. Intuitively, nutrient content will always be higher on a DM compared to AF basis for any feed. Feeds having more water content (i.e., pastures) will have much lower nutrient content than dry hay when compared on an as fed basis. From **Table 1**, it can be seen the pasture has much lower nutrient content on an AF basis; however, when corrected for water content, both pasture and hay have equal nutrient content. To appropriately compare these two feeds equally, nutrient content needs to be converted to a DM basis. Feed moisture determinations also facilitate calculations and monitoring of animal DM intake. Finally, DM determinations can be used to evaluate whether or not feed moisture content is within expected ranges. For hay or any dry feed, moisture content should not exceed 15%, as this amount of moisture is necessary to promote mold growth.

Fiber

The detergent feed analysis system is used to characterize fiber or total cell wall content of a forage or feed. That portion of a forage or feed sample insoluble in neutral detergent is termed *neutral detergent fiber (NDF)*, which contains the primary components of the plant cell wall, namely, hemicellulose, cellulose, and lignin. As cell wall production increases, as occurs in advancing plant maturity, NDF content will increase. As NDF content of a feed increases, dry matter intake will decrease and chewing activity will increase. Within a given feed, NDF is a good measure of feed quality and plant maturity. For legume forages, NDF content below 40% would be considered good quality, while above 50%

would be considered poor. For grass forages, NDF < 50% would be considered high quality and > 60% as low quality.

Another measure of fiber is *acid detergent fiber* (ADF), a subset of NDF. Acid detergent fiber contains the poorly digestible cell wall components, namely, cellulose, lignin, and other very resistant substances. Due to its nature, ADF is often used to predict energy content of feeds. Like NDF, ADF is a good indicator of feed quality; higher values within a feed suggest lower-quality feed. A goal would be to have < 35% ADF in either legume or grass forages. Refer back to table 1 shown in the first column (page 33 in June 2006 issue) for the changes in NDF and ADF with forage maturity.

Crude Protein (CP)

Feed protein content is often considered a good determinant of quality. In actuality protein cannot be directly measured, it is estimated from feed sample nitrogen (N) content. On average all biological proteins contain 16% N, therefore protein content is estimated by multiplying N% by 6.25 (6.25 = 1) 0.16). Thus, crude protein does not differentiate between N in feed samples coming from true protein or other nonprotein nitrogen (NPN) compounds, nor does it differentiate between available and unavailable protein.

Although issues have been raised concerning application of crude protein as a feed measure, it continues to be a commonly used measure of feed quality. Crude protein content is very different across feeds, but within a feed, higher protein is usually associated with higher quality. This certainly is true in forages. As forages mature, their crude protein is diluted with increasing fiber content. Forage fertilization practices can alter this relationship, suggesting crude protein should not be solely used as a quality criterion without evaluating fiber content.

Energy

Energy content is often used to compare feeds and evaluate quality. Feed energy content is not directly measured like other nutrients but derived through regression equations. Traditionally ADF alone or with CP were used to predict energy value of various feeds. Most laboratories report feed energy values based on cattle equations, reporting total digestible nutrients (TDN) and net energy (NE) values. The question is how applicable are these predicted values to camelids? Cattle TDN values are the best estimate we have and should reasonably reflect feed energy for llamas and alpacas given the similarity in digestive function. In comparison, predicted cattle feed energy availability would be inappropriate for use in swine or horse diets given anatomic and physiologic differences in digestive capacity. However, in considering the differences in fiber degradability between ruminants and camelids, one would anticipate that cattle energy predictions may be too low for lower-quality forages.

In Figure 1, a large portion of feed carbohydrates, especially those associated with higher digestibility and glucose production, are not measured. The neutral detergent soluble carbohydrate fraction of feed is termed *nonfiber carbohydrates* (NFC). This fraction is not directly measured, but determined by difference. Inherently, all laboratory analytical method errors associated with other feed fractions will be compiled into the NFC fraction. Although susceptible to error, NFC represents a highly available portion of a feed and as such positively reflects on evaluation of feed quality. More recently some laboratories have offered an enzymatic analysis for feed starch content; helping to further define the more digestible portion of NFC, termed *nonstructural carbohydrates* (NSC). Higher values for NFC and NSC would reflect higher quality forages. For grasses and legume forages, NFC values >20 and >30%, respectively, would be considered higher quality, especially if associated with lower fiber values.

Other Feed Fractions.

Additional analyses may be completed on a feed sample, including fat content (ether extract) and mineral analysis. Ether extract is a chemical method by which all lipid (fat) soluble compounds are extracted by being dissolved in ether (Figure 1). This technique is of little value in evaluating feed quality except in the cases of comparing feeds with high fat content.

Total feed mineral content can be measured by a procedure where the feed sample is completely combusted into ash. This does not separate out any individual minerals and does not separate macro- and microminerals of interest from silica and other less important minerals. Selected macrominerals (calcium, phosphorus, magnesium, potassium, sodium, and sulfur) and microminerals (iron, copper, zinc, manganese, and molybdenum) can be determined using sophisticated wet chemistry atomic absorption spectroscopy. As previously stated, NIR analyses are not very accurate in determining feed mineral content. Mineral analysis is not always done since it is the most expensive test. Feed mineral content has no bearing on feed quality evaluation, but can provide insight as to the type of mineral supplement required.

Visual Assessment of Forage Quality

Although forage testing is the most definitive method of determining forage quality, it often is not complete. Associated costs, lack of laboratory availability or constant forage turnover are the most often reasons people cite for not testing their forages. The first two reasons are not good excuses; however, the third is an issue on many farms that purchase small lots of hay often. One can use their various senses to evaluate small amounts of forages, though sensory evaluation does not provide any sense of nutrient content. Table 2 summarizes visual and chemical analysis of forages with guidelines for assessing quality.

Although the general idea is that forages grown in North America are of better quality than South American forages, forage quality can not be ignored in our feeding programs. Many factors influence forage quality, the most critical being plant maturity. Feeding programs consisting of low quality forage and limited variety of feedstuffs can potentially result in protein-energy malnutrition, failure to thrive and hepatic lipidosis disease problems. There is no best single feeding program that fits all situations, but extremes of only high quality alfalfa hay or low quality grass hay are not appropriate. Feeding programs with pasture access may have the greatest application, allowing the animals to best express their selective feeding behaviors. When hay is the primary forage in a feeding program, critical assessment of nutrient content via laboratory analysis is highly recommended. Further questions or comments about forage quality and nutrition are welcomed.

Van Saun, R.J. Determining forage quality: Understanding feed analysis. Lamalink.com August, 2006;3(8):18-19,22,24, 25-26.

Figure 1. 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.

[**]Newer methods are being used to measure starch content.

[+]Determined by difference (100 - CP - EE - NDF - Ash).

Van Saun, R.J. Determining forage quality: Understanding feed analysis. Lamalink.com August, 2006;3(8):18-19,22,24, 25-26.

Table 1. Comparison of nutrient content expressed on As Fed (AF) or Dry Matter (DM) basis for generic grass pasture and hay.

	Nutrient Density Basis*	% Nutrient Content				
		DM	**Protein**	**NDF**	**ADF**	**Calcium**
Grass Pasture	AF	20	2.2	11.0	8.0	0.12
	DM	100	11.0	55.0	40.0	0.60
Grass Hay	AF	90	9.9	49.5	36.0	0.54
	DM	100	11.0	55.0	40.0	0.60

*Conversion formula: As Fed nutrient content = DM nutrient content x DM ratio or DM nutrient content = As Fed nutrient content/DM ratio. DM ratio is 0.2 for pasture and 0.9 for hay in this example.

Table 2. Sensory evaluation and chemical tests in assessing forage (pasture and hay) quality.

Testing Method	Description/Comments
Sensory Evaluation	
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 the stems or leaves are more obvious; good-quality legume forages will have a high proportion of leaves, and stems will be less obvious and fine
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, and 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
Chemical Testing	
Moisture/Dry Matter	Measures amount of moisture in forage; moisture content will determine how well the forage will store without molding; Goal for any hay <15% moisture (>85% dry matter)
Neutral Detergent Fiber	Measures total cell wall content of plant and indicates maturity; the higher the value, the more mature and lower quality the forage; Goal < 40% Alfalfa and < 55% Grasses
Acid Detergent Fiber	Measures the more indigestible portion of cell wall and reflects degree of lignification; Higher values indicate more mature, lower quality forages; Goal: < 35% Alfalfa and < 35% Grasses
Crude Protein	Crude protein content reflects maturity of forage as well as fertilization amount; Good-quality forages generally will have higher protein content; Goal > 9% Grasses and >15% Alfalfa

Van Saun, R.J. Determining forage quality: Understanding feed analysis. Lamalink.com August, 2006;3(8):18-19,22,24, 25-26.

Van Saun, R.J. Determining forage quality: Understanding feed analysis. Lamalink.com August, 2006;3(8):18-19,22,24, 25-26.