Texas Cooperative EXTENSION
The Texas A&M University System

L-5481
01/07

Defining FORAGE Quality

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Forages with good quality are the main asset of any livestock operation, and they are also the foundation of most rations in a forage-based diet. The available nutrients that a forage carries affect individual animal production (e.g., gain per animal), while the amount of forage produced affects production per acre. Forages possess a mixture of chemical, physical and structural characteristics that determine the quality of that pasture or the accessibility of nutrients to that animal.

The decision whether to use hay (grazing versus haying) or how to select the best hay available should be based on forage quality. Forage analyses are important because they reflect the quality of the forage. In addition, they are a relatively inexpensive tool to evaluate the nutritive value of the forage to be grazed, or the hay to be purchased or marketed.

Knowing what affects forage quality will also help making appropriate selection of forages and supplements that will match animal requirements and result in economically optimum livestock performance.

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Forage Quality

Forage quality can be defined in many ways. It is associated with nutrients, energy, protein, digestibility, fiber, mineral, vitamins and, occasionally but not usually, animal production. In practical terms, forage quality has been referred to as "milk in the bucket." In programs for Texas producers, it has been described as "pounds on the scale," and some individuals even incorporate reproduction concerns in defining forage quality as "calves on the ground." For beef, dairy, horse, sheep or goat production, the ultimate quality test of forage is animal performance.

In defining forage quality, this publication distinguishes between forage quality and forage nutritive value even though these terms are usually used interchangeably. *Forage nutritive value* usually refers to concentration of available energy (total digestible nutrients, or TDN) and concentration of crude protein. *Forage quality* is a broader term that not only includes nutritive value, but also forage intake. In practice, animal performance of grazing animals reflects forage quality.

Where forages are the main diet component, forage quality of a pasture or crop is determined by animal product (e.g., milk, pounds of beef, performance in a horse). If the animal has the genetic potential, animal production of forage-based diets depends on the nutritive value of forage consumed – the crude protein concentration, available energy and minerals that are in the forage tissue. Most importantly, animal performance depends on the intake of the forage.

When grazing management decisions result in overgrazed pastures, they usually stem from high stocking rates for a long time. This means that the opportunity to select plant species or plant parts of higher nutritive value decreases; and, consequently, forage intake of animals declines.

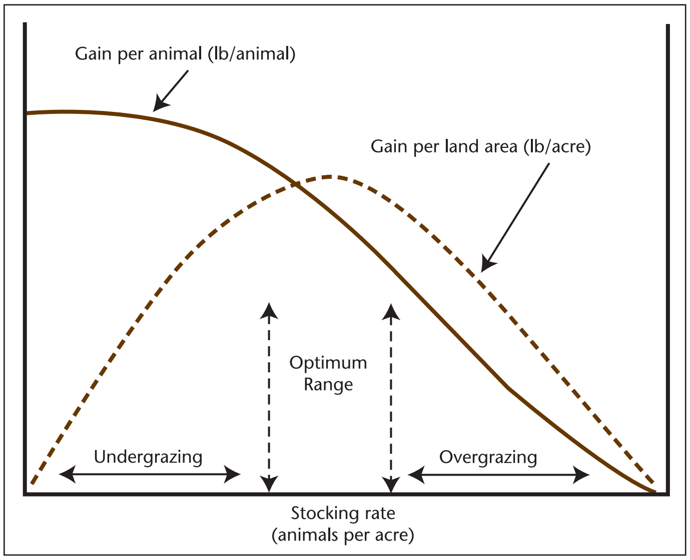

Figure 1. Effects of stocking rate on gain per animal and gain per acre. (Adapted from Mott, 1973)

Figure 1 illustrates how forage quality, measured by animal performance (daily gains), decreases with increments in stocking rate. In the example, the initial nutritive value of the pastures can be adequate and even exceed animal requirements when pastures are understocked. However, under high stocking rates, the animal's ability to select forages diminishes over time; and the amount of forage available also decreases.

In overgrazed situations, management creates scarce forage by stocking too many animals. This causes consumption per animal to decrease because the forage resource is in short supply. Therefore, fewer nutrients are consumed per animal with overstocking.

Change in Forage Quality

In a pasture not every plant will have the same nutritive value. This is because there are different plant characteristics that directly or indirectly affect forage quality.

The main factors affecting quality of a stand are maturity and weather conditions. *Maturity*, or stage of growth, is the principal factor responsible for declining forage nutritive value. As the plant advances in growth beyond the first couple of weeks (where protein and digestibility are at its highest), stem growth develops as well as deposition of fibrous components at the plant cell level.

With advancing maturity, one of the main chemicals deposited internally in the plant cell walls is lignin. *Lignin* is a component of fiber that is essentially indigestible, accumulates mostly at maturity and acts as a barrier to fiber degradation by rumen microbes. The microbial population in the rumen leads to degrading of the forage fiber, thereby making it unavailable for the animal. If the forage is too mature, fiber increases. In addition, digestibility of the forage declines like crude protein (CP) does in the forage tissue. This decline is more pronounced and sudden in warm season perennial grasses — especially, in plant tissue older than 35-40 days.

Table 1 shows a sharp decline in digestibility and crude protein of Coastal bermudagrass after week 5 (35 days). As the forage ages, digestibility and protein drop and fiber (ADF, lignin) increases.

Another major factor affecting forage quality is weather. Poor storage and harvest conditions also lead to sugar losses due to weathered forage. Forage that is harvested and not properly dried continues to respire, causing soluble sugars to decrease.

Table 1. Nutrient composition of Coastal bermudagrass as affected by maturity (age of forages in weeks). (Adapted from Mandevu et al. 1999)

Age of grass	Digestibility	Crude protein	ADF	Lignin
(weeks)	--------------- % ---------------			
4	60	18	29	4
5	59	18	30	4
6	56	16	31	5
7	53	13	33	6

Forage Analysis

Because the forage plant characteristics are primarily sensitive to changes over time, regular and *timely* analyses of forage are required to know if the forage meets the daily nutritional requirements of the animals. Commercial laboratory analyses (wet chemistry or near infrared test) include measurement of moisture, protein and fiber (Table 2).

Table 2. Example of forage analysis result from bermudagrass hay sample (first cutting in 2006, fertilized with 80 lb N/acre) from producer in central Texas. (Soil, Water, and Forage Testing Laboratory, Texas A&M University, *http: // soiltesting.tamu.edu*)

Item	Moisture	Dry matter (DM)
	-------------------- % --------------------	
	As Received Basis	Dry Matter Basis
Moisture, %	5.9	0
Dry Matter, %	94.1	100
Crude Protein, %	9.7	10.3
Acid Det. Fiber, %	35.2	37.5
Neutral Det. Fiber, %	66.0	70.1
TDN Est., %	57.0	60.6

Intake and energy or TDN cannot be measured directly because this requires testing with animals which may not be practical for all commercial laboratories. Thus, TDN and intake are estimated from equations based on research results where they undergo animal testing.

Defining Forage Quality also addresses two indices commonly used to represent forage quality because they are often misused with warm season forages: relative feed value (RFV) and relative forage quality (RFQ).

Moisture

Moisture content is reported usually as a wet and a dry matter (DM) basis. *Wet basis* is important because it indicates how much "fresh" forage would be required to meet DM requirement of the animals. *Dry matter basis* is calculated as if the forage had no moisture and makes valid comparisons among different forages. Forage moisture will vary depending on how the forage is fed (Table 3).

Table 3. Moisture and dry matter concentration of different forms of forage.

Item	Moisture	Dry matter (DM)
	-------------------- % --------------------	
Hay	8–15	85–92
Silage	65–75	25–45
Fresh forage grazing	70–85	15–30

Energy

The main sources of energy for ruminants come from carbohydrate fermentation in the rumen.

Forages they consume have two basic types of carbohydrates:

- those associated with cell contents (soluble carbohydrates, highly digestible, easily broken down by the rumen microbes)
- those more resistant to degradation, usually associated with the cell wall constituents (consisting of fiber components subject to partial degradation by rumen microbes).

As an indicator of concentration of available energy, TDN is calculated as the sum of the digestible protein, digestible crude fiber, digestible nitrogen free extract and 2.25 times the digestible fat. Although TDN has been in use for many years, this measure is still an easily understood and acceptable measure of nutritive value.

These nutrients vary with maturity; the older the forage, the lower TDN value it will have, and vice-versa. Values of TDN also vary with forage type: Alfalfa (60-70 percent) > Cool Season Grasses/Clovers (55-68 percent) > Warm Season Grasses (45–65 percent). Some examples of TDN for different forages are bermudagrass, 55-65 (for 28-30 days old); bermudagrass, 40-45 (for mature, low quality forage); prairiegrass hay, 45-60 (depending on maturity); pearl millet, 70; and kleingrass, 70.

Crude protein

Proteins plus energy are the most important nutrients for livestock, as they support rumen microbes that consequently degrade forage. True proteins make up 60-80 percent of the total plant nitrogen (N), with soluble protein and a small portion of fiber-bound N making up the remainder. As the following indicates, values of forage protein concentrations vary considerably (depending on species, soil fertility and plant maturity): alfalfa, 18-25 percent; corn leaves, 6-14 percent; and Coastal bermudagrass leaves, 4-18 percent.

Crude protein is measured indirectly by determining the amount of N in the forage plant and multiplying that value by 6.25. The assumption is that N constitutes about 16 percent of tissue protein in the forage (100/16= 6.25). If determining CP of material other than leaf and stem tissue, the constant may be lower as in seed tissue protein.

The physiological state of the animal influences the ruminant CP requirement. For example, a lactating or a growing animal will have higher requirements than a mature, non-lactating animal. The following shows how crude protein concentration varies with forage type: Legumes (12-25 percent) > Cool Season Grasses (8-23 percent) > Warm Season Grasses (5–18 percent).

In examining protein's benefits for livestock, it is important to distinguish between sources of nitrogen accordingly:

- **Nitrate nitrogen (NO3-N).** Commonly referred to as nitrates, this is a form of N that accumulates in growing plant parts (e.g., leaf and stems) under certain conditions (high N fertilization, drought, frost). They can cause nitrate toxicity if excessive levels are consumed. Nitrate contents of less than 0.1 percent nitrate nitrogen are safe for all livestock. Feeds containing between 0.1 and 0.2 percent nitrate nitrogen should be limited to half of the daily intake of pregnant animals. Feeds exceeding 0.4 percent nitrate nitrogen should be avoided, as they are likely to cause nitrate toxicity.

  Never feed livestock high-nitrate hay free choice. For example, a drought may cause forages such as johnsongrass, sudangrass, or sorghum and sorghum hybrids to accumulate NO3-N and be stored in lower leaves and stems. However, nitrate levels can change daily, so test hay if you anticipate a nitrate problem.
- **Ammonium nitrogen.** Ammonium N results from fermentation resulting from the breakdown of protein. Low values (less than 10 percent) are good, while high values (greater than 15 percent) are undesirable because ammonia toxicity can occur if blood ammonia levels increase rapidly. Some ammonia is required by rumen bacteria for optimal fiber digestion.

Fiber

Fiber refers to the cell wall constituents of hemicelluloses, cellulose and lignin. While fiber extraction is the most widely used system for analyzing forages, it does not measure digestibility.

Fiber extraction in forages is accomplished with the detergent analyses system — a process defined by the following:

- **Neutral Detergent Fiber.** The NDF values represent the total fiber fraction (cellulose, hemicellulose and lignin) that make up cell walls (structural carbohydrates or sugars) within the forage tissue. Values vary from 10 percent in corn grain to 80 percent in warm season grass straw. Values of NDF for grasses will be higher (60-65) than for legumes (45-45). A high NDF content indicates high overall fiber in forage; so, the lower the NDF value, the better.
- **Acid Detergent Fiber.** The ADF values represent cellulose, lignin and silica (if present). The ADF fraction of forages is moderately indigestible. Forages range from 3 percent in corn grain to 50 percent ADF in warm season grass straw. Animals and laboratory testing have shown that high ADF values are associated with decreased digestibility; therefore, a low ADF is better.

Neutral detergent fiber has traditionally been used as a predictor of forage intake, while ADF has been used as a predictor of forage digestibility. These relationships often hold true for mixed diets, but they can be misleading when forage is fed alone. These relationships are used to calculate relative feed value (RFV).

Relative Feed Value

The Relative Feed Value is an index representing forage quality. This is one of the systems used by forage testing laboratories for many years.

The RFV index uses NDF and ADF as predictors of forage quality. The NDF content is correlated with intake and ADF with digestibility of the forage within the context of temperate forages – particularly, alfalfa. More specifically, the index ranks forages according to a calculation based on intake potential (predicted from NDF) and digestible DM (predicted from ADF) of alfalfa at full bloom.

The calculated value of RFV=100 is an indicator of a forage quality that can be equated to alfalfa at full bloom. Thus, the index provides a number that can be associated with different quality hays of alfalfa. If, for example, alfalfa is at pre-bloom, the forage would have higher nutritive value (Table 4); and the RFV for alfalfa would be higher (RFV=164). Hay buyers and sellers have used this index for estimating hay quality. Thus, the higher the quality, the higher the RFV. Consequently, this means a higher price for that hay.

This index is a valid comparison only when applied to temperate species, since it was developed using alfalfa (a cool season perennial legume). The RFV should not be applied to warm season forages; therefore, you should limit its use with predictions with cool season species.

Table 4. Alfalfa hay grade and the Relative Feed Value (RFV) versus forage maturity or stage of development of alfalfa forage. (Adapted from Stokes and Prostko, 1998)

Hay grade	RFV	Maturity
Prime	>151	Bud stage
1	125–151	10% bloom
2	103-124	50% bloom
3	87–102	100% bloom
4	75–86	Pods

Relative Forage Quality (RFQ)

The Relative Forage Quality (RFQ) index is a newer system that was developed to have the same mean and range as RFV. While it can be substituted for RFV when necessary, its calculations are different. They are based on values of CP, NDF, ADF, fat, ash and NDF.

The advantage of RFQ over RFV is that RFQ considers the digestible fiber. This becomes relevant when testing southern forages — particularly, warm season grasses that are high in fiber that is highly digestible. The grass will be more accurately tested when using RFQ, resulting in better matching of forage nutrient supply with cattle nutrient demand (Table 5). The values of RFQ can be applied to all forages (cool season and warm season or tropical) except for corn silage. This makes RFQ a much more versatile forage quality index.

Table 5. Relative Forage Quality (RFQ) and the nutritional needs of cattle. (Adapted from Undersander, D. 2003).

Relative Forage Quality	Cattle Nutrients Demand
140–160	Dairy, 1st trimester Dairy calf
125–150	Dairy, last 200 days Heifer, 3–12 months Stocker cattle
115–130	Heifer, 12–18 months Beef cow-calf
100–120	Heifer, 18–24 months Dry cow

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