Defining Forage Quality[1]

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Forages are a major asset of any livestock operation and the foundation of most rations in a forage-based livestock diet. The available nutrients in a forage influence individual animal production (e.g., gain per animal), while the amount of forage produced affects production per acre.

Forages contain a mixture of chemical, physical, and structural characteristics that determine the quality of a pasture and the accessibility of nutrients to the target animal.

The decision of whether to use conserved forage (hay) or to allow livestock to graze—as well as choices related to the purchase and selection of hay—should be based on forage quality. Forage analyses, which are important because they describe the quality of the forage, 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 in making appropriate selections of forages and supplements that will match animal requirements and result in economically optimum livestock performance.

Forage Quality

Forage quality can be defined in many ways. Forage quality is associated with nutrients, energy, protein, digestibility, fiber, mineral, vitamins, and occasionally animal production. For beef, dairy, horse, sheep, or goat production, the ultimate quality test of a forage is animal performance. In practical terms, forage quality has been referred to as “milk in the bucket.” In programs for producers, forage quality has been described as “pounds on the scale,” and sometimes livestock reproductive success is incorporated in defining forage quality as “calves on the ground.”

In defining forage quality, this publication distinguishes between forage quality and forage nutritive value even though these terms are often used interchangeably. However, forage nutritive value typically refers to concentration of available energy (total digestible nutrients, or TDN) and concentration of crude protein. By contrast, 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 component of livestock diet, 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 on a forage-based diet 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 intake of the forage. Overgrazed pastures are generally the result of overstocking, which, in turn, diminishes the ability of the animal to select plant species or plant parts of higher nutritive value. Consequently, in overgrazed pastures forage intake declines.

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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.

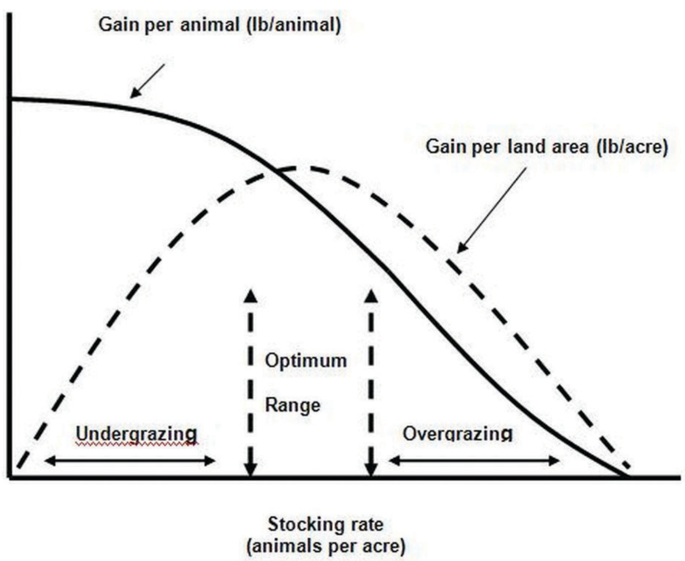

Figure 1. Effects of stocking rate on gain per animal and gain per acre.
Credits: Adapted from Mott 1973

In overgrazed pastures, management creates scarce forage by stocking too many animals. As a result, consumption per animal decreases because the forage resource is in short supply. Therefore, fewer nutrients are consumed per animal when pastures are overstocked.

Change in Forage Quality

In any pasture, not every plant will have the same nutritive value because different plant characteristics directly or indirectly affect forage quality.

Weather conditions and forage maturity are the primary factors affecting quality of a stand. 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 highest), stem growth advances, 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, a component of fiber, is essentially indigestible, accumulates mostly at plant 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 is more prevalent in the forage, and digestibility of the forage declines; crude protein (CP) also declines 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.

Additionally, poor storage and harvest conditions lead to sugar losses when forage becomes weathered. Forage that is harvested and not properly dried continues to respire, causing soluble sugars to decrease. Other factors affecting forage quality are fertilization, season, pre- and post harvest management, and presence of anti-quality factors.

Forage Analysis

Especially because forage plant characteristics change with maturity, regular and timely analyses of forage are required to determine whether a forage meets the daily nutritional requirements of the animals. Commercial laboratory analyses (wet chemistry or a near-infrared test) include measurement of moisture, protein, and fiber (Table 1).

Table 1. An Example of the Results of a Forage Analysis of a Tifton 85 Bermudagrass Hay Sample Cut at 24 Days Regrowth, Second Cutting.

Item	Moisture	Dry Matter
	As Received Basis	Dry Matter Basis
	---------------- %	------------
Moisture	8.80	0.00
Dry Matter	91.20	100.00
Crude Protein	16.90	18.60
Acid Det. Fiber	40.40	44.30
Neutral Det. Fiber	64.80	71.10
TDN Est.	56.00	62.00

Intake and energy or TDN cannot be measured directly from forage because these measurements require testing animals, a test that may not be practical for all commercial laboratories. Thus, TDN and intake are estimated from equations derived from research results of animal testing.

This publication also addresses, below, two indices commonly used to represent forage quality: relative feed value (RFV) and relative forage quality (RFQ). These indices are often misused with warm-season forages.

Moisture

Moisture content is usually reported on a wet and a dry-matter (DM) basis. Wet basis 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. This calculation allows for the most accurate comparison among different forages. Forage moisture will vary depending on forage type and how the forage is fed (Table 2).

Table 2. Moisture and Dry Matter Concentration of Different Forms of Forage.

Type	Moisture	Dry Matter
	------------%--------------	
Hay	8–15	85–92
Silage	65–75	25–45
Fresh forage	70–85	15–30

Energy

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

Forages that ruminants consume have two basic types of carbohydrates:

- Those associated with cell contents (soluble carbohydrates, which are highly digestible, easily broken down by rumen microbes).
- Those associated with the cell wall constituents (fiber components, which are subject to partial degradation by rumen microbes).

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

Forage nutrients vary with maturity; the older the forage, the lower the TDN value.

Values of TDN also vary with forage species: Alfalfa (60%–70%) > Cool Season Grasses/Clovers (55%–68%) > Warm Season Grasses (45%–65%). Some examples of TDN for different forages are bahiagrass, 55%–60% (at 28–30 days old), bahiagrass 40%–45% (for mature, low-quality forage); bermudagrass, 55%–65% (at 28–30 days old); bermudagrass, 40%–45% (for mature, low-quality forage); and pearl millet, 70%.

Crude Protein

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

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% of protein in the leaf and stem tissue of 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 CP requirements than a mature, non-lactating animal. The following shows how crude protein concentration varies with forage type: Legumes (12%–25%) > cool-season grasses (8%–23%) > warm-season grasses (5%–18%).

In examining protein's benefits for livestock, be careful to distinguish between sources of nitrogen accordingly:

- **Nitrate nitrogen (NO3-N).** Commonly referred to as nitrates, this form of N accumulates in growing plant parts (e.g., leaf and stems) under certain conditions (high N fertilization, drought, and frost). Nitrates can cause nitrate toxicity if excessive levels are consumed. Nitrate contents of less than 0.1% nitrate nitrogen are safe for all livestock. Feeds containing between 0.1 and 0.2% nitrate nitrogen should be limited to half of the daily intake of pregnant animals. Feeds exceeding 0.4% 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%) are good, while high values (greater than 15%) 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, this system 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, hemicelluloses, and lignin) that make up cell walls (structural carbohydrates or sugars) within the forage tissue. Values vary from 10% in corn grain to 80% 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; 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 in ADF values from 3% in corn grain to 50% in warm-season grass straw. High ADF values are associated with decreased digestibility. Therefore, a low ADF is better.
- **Neutral Detergent Fiber Digestibility.** The NDF—total fiber fraction nutritional availability—is not uniform across forages. The NDF digestibility of warm-season forages is highly variable and is usually assessed by measuring NDF in vitro digestibility at 48 hours incubation time. In vitro NDF digestibility measures how much NDF a ruminant can digest at a maintenance level of intake. Values of NDF digestibility for warm-season grasses are variable; typical values may range from 50% to 75% NDF. 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 and are used to calculate relative feed value (RFV). But such calculations can be misleading when forage is the sole source of livestock nutrition.

Relative Feed Value

The Relative Feed Value (RFV) is an index representing forage quality and 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; ADF is correlated with digestibility of the forage within the context of temperate forages, particularly alfalfa. More specifically, the RFV 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 3); 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 and the higher price for that hay.

Table 3. Relationships among Alfalfa hay grade, Relative Feed Value (RFV), and alfalfa forage maturity. (Adapted from Stokes and Prostko 1998).

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

Because this index was developed using alfalfa (a cool-season perennial legume), the index is a valid comparison only when applied to temperate species. The RFV index should not be applied to warm-season forages. Limit use of the RFV index to predictions with cool-season forages.

Relative Forage Quality

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

The advantage of RFQ over RFV is that RFQ considers the digestible fiber, which becomes relevant when testing southern forages, particularly warm-season grasses that are high in fiber that is highly digestible. The grass can be more accurately categorized when using RFQ, resulting in better matching of forage nutrient content with cattle nutrient requirements (Table 4). The values of RFQ can be applied to all forages (cool-season and warm-season or tropical), except for corn silage, making RFQ a much more versatile forage-quality index.

Table 4. Relative Forage Quality (RFQ) and the Nutritional Needs of Cattle. (Adapted from Undersander, D. 2003)

Relative Forage Quality	Cattle Nutrients Requirements
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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