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Defining Forage Quality

Subtitle: Nutritive Value of Southern Forages

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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. Forages affect individual animal performance. The available nutrients that a forage carries affects individual animal production (i.e. 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.

When forced to think about forage quality, different terms come to mind; among others: nutrients, energy, protein, digestibility, fiber, mineral, vitamins and, occasionally but not usually, we may think about animal production. In practical terms forage quality has been defined as "milk in the bucket"[a]. In programs for Texas producers, it has been defined as "pounds on the scale", and some even allow reproduction concerns when stating …"forage quality is calves on the ground". For beef, dairy, horse, sheep, or goat production, the ultimate quality test of forage is animal performance.

This publication discusses the definition of forage quality, the main factors affecting forage quality, and the components and importance of forage analyses.

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[a] See Adesogan et al 2006 in list of references.

Forage Quality?

In defining forage quality, a distinction will be made between forage quality and forage nutritive value. Most of the times, these terms are used interchangeably but in this definition of forage quality we will follow those that make the distinction between the two terms. Forage nutritive value usually refers to concentration of available energy (total digestible nutrients, 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 (milk, pounds of beef, performance in a horse, etc.). If the animal has the genetic potential, animal production of forage-based diets depends on the nutritive value of forage consumed. In other words, how much crude protein concentration, available energy, and minerals are in the forage tissue, but most importantly, animal performance depends on the intake of the forage.

In instances where grazing management decisions (deliberate or default) result in overgrazed pastures (usually, high stocking rates for an extended period of time), the opportunity to select plant species or plant parts of higher nutritive value decreases and, consequently, forage intake of animals declines. Figure 1 illustrates how forage quality, measured by animal performance (daily gains), decreases with increments in stocking rate. In the example, when pastures are under-stocked, the initial nutritive value of the pastures can be adequate and even in excess of animal requirements; 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; thereby, causing consumption per animal to decrease because the forage resource is in short supply. Bottom line: with overstocking fewer nutrients are consumed per animal.

Why and how does Forage Quality change?

In a pasture not every plant will have the same nutritive value. There are different plant characteristics that directly or indirectly affect forage quality. The main factors affecting quality of a stand are maturity and weathered 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 is responsible for degrading the forage fiber and making it available to the animal. If the forage is too mature, fiber increases and digestibility of the forage declines as does crude protein (CP) in the forage tissue. This decline is more pronounced and sudden in warm-season perennial grasses especially in plant tissue that is older than 35-40 days. In Table 1 we can observe how there is a sharp decline in digestibility and crude protein of Coastal bermudagrass after week 5 (35 days) but an increase in fiber (ADF and lignin). As the forage ages, digestibility and protein drop while fiber increases as indicated by the arrows.

Table 1. Nutrient composition of Coastal bermudagrass as affected by maturity (age of forages in weeks).

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

Adapted from Mandevu et al. 1999)

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

What is in a Forage Analysis?

Because the forage plant characteristics are primarily sensitive to changes over time, timely and regular 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 (see Table 2). Intake and energy or total digestible nutrients (TDN) can not be measured directly because this requires testing with animals which may not be practical for all commercial laboratories.

Table 2. Example of forage analysis result from bermudagrass hay sample (1st 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

Thus, TDN and intake are estimated from equations based on research results where they undergo animal testing. In addition, two indices commonly used to represent forage quality will be briefly discussed as they are often misused when it comes to warm-season forages: relative feed value (RFV) and relative forage quality (RFQ).

Moisture

Moisture content is reported usually as wet and dry matter (DM) basis. Wet basis is important because it gives an indication of how much ‘fresh’ forage would be required to meet DM requirement of the animals. The second one, DM, is calculated as if the forage had no moisture and this is used to make valid comparisons among different forages. Forage moisture will vary depending on how the forage is fed (see 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 are the products of carbohydrate fermentation in the rumen. Forages have two basic types of carbohydrates: 1) those associated with cell contents (soluble carbohydrates, highly digestible, easily broken down by the rumen microbes), and 2) those more resistant to degradation, usually associated with the cell wall constituents (which consist of fiber components, subject to partial degradation by rumen microbes). Total digestible nutrients (TDN) is an indicator of concentration of available energy. It 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. Total digestible 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%) > Cool-Season Grasses/Clovers (55-68%) > Warm-Season Grasses (45–65%). 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; kleingrass, 70.

Crude protein

Proteins together with energy are the most important nutrients for livestock as they support rumen microbes that in turn 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. Forage protein concentrations vary considerably depending on species, soil fertility, and plant maturity: alfalfa, 18-25%; corn leaves, 6-14%; 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 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. Ruminant CP requirement is influenced by the physiological state of the animal (a lactating or a growing animal will have higher requirements than one a mature, non-lactating animal). Crude protein concentration varies with forage type: Legumes (12-25%) > Cool-Season Grasses (8-23%) > Warm-Season Grasses (5 – 18%).

Nitrate nitrogen (NO_3-N): Commonly referred to as nitrates, this is a form of N that accumulates in growing plant parts (leaf, stems, etc) under certain conditions (high N fertilization, drought, frost), and can cause nitrate toxicity if excessive levels are consumed. Nitrate contents of less than 0.1% nitrate nitrogen are considered safe for all types of 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 high-nitrate hay free choice; for example after drought condition, forages such as johnsongrass, sudangrass, or sorghum and sorghum hybrids, tend to accumulate NO_3-N and be stored in lower leaves and stems, however, nitrate levels can change from day to day and even within the same day. Test hay if a nitrate problem is anticipated.

Ammonium nitrogen: Ammonium N is a product of fermentation resulting from the breakdown of protein. Low values (<10%) are good, while high values (>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. Fiber extraction in forages is accomplished with the detergent analyses system, and is presently the most widely used system for analyzing forages. However, it does not measure digestibility.

1. 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% 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.

2. 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% in corn grain to 50% 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 desired.

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

Relative Feed Value

The Relative Feed Value (RFV) is an index used to represent forage quality. This system, among others, has been 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 in the context of temperate forages, particularly, alfalfa. More specifically, the index ranks forages based on 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 to different quality hays of alfalfa. If, for example, alfalfa is at pre bloom, the forage would have higher nutritive value and the RFV for alfalfa would be higher (RFV= 164) (Table 4). This index has been used by hay buyers and sellers as a mean of estimating hay quality. Thus, the higher the quality the higher the RFV and consequently the higher pricing that may be obtain for that hay.

This index is a valid comparison <u>only</u> when applied to temperate species since it was developed using alfalfa (a cool season perennial legume). It should not be applied to warm-season forages; therefore, use of RFV should be limited 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 and can be substituted for RFV when making management decisions. Calculations are different from RFV, and are based on values of CP, NDF, ADF, fat, ash, and NDF. The advantage of RFQ over RFV is that RFQ takes into consideration the digestible fiber—an aspect that RFQ does not. 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 (see Table 5). The values of RFQ can be applied to all forages (both cool season and warm season or tropical) with the exception of 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 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

Concluding Remarks

Understanding forage quality and the factors that affect its constituents will help improve livestock production by making decisions that optimize forage nutritive value and intake. The decision to use hay or not (grazing vs. 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 and they are a relatively inexpensive tool to evaluate the nutritive value of the forage to be grazed or 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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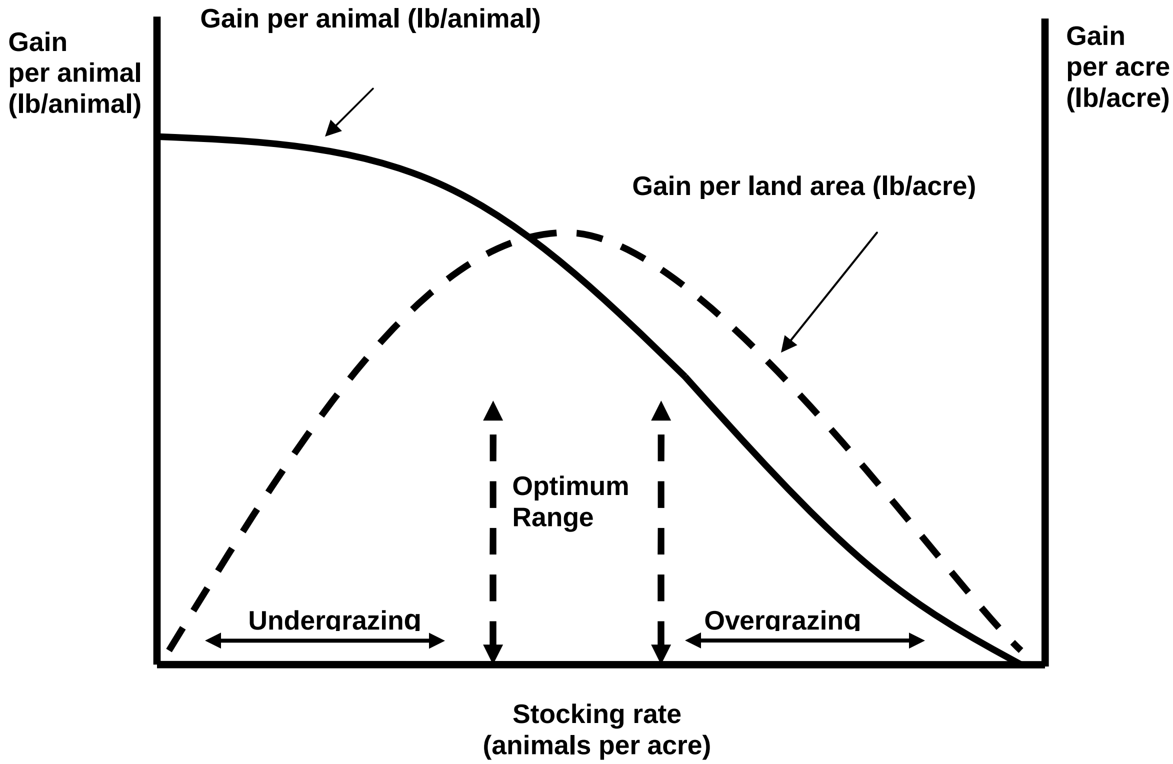

Figure 1. Effects of stocking rate on gain per animal and gain per acre. (Adapted from Mott, 1973)