Forage Quality in Perspective

Fluctuations in milk prices, feed costs, and government programs are forcing dairy farmers to become more efficient with their farm operation. Since feed accounts for approximately one-half of the total cost of producing milk, and high-quality forage optimizes the productivity of the animals, increasing the quality of forage available is one of the best methods of improving overall feeding efficiency. To effectively produce high-quality forage, it is necessary to understand what forage quality is and to keep the factors influencing forage quality in perspective.

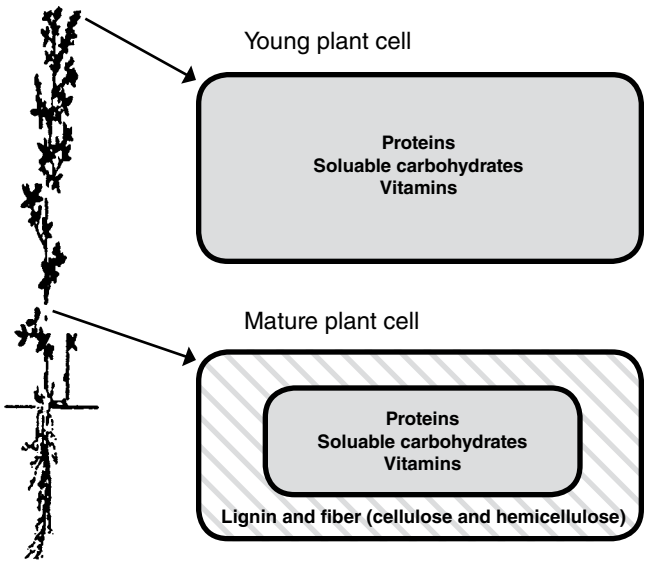
WHAT IS FORAGE QUALITY?

Forage quality is defined as the sum total of the plant constituents that influence an animal's use of the feed. Along with its quality, the overall potential feeding value of a forage feed is influenced by the form in which it is fed (e.g., particle size), the palatability of the forage, and the quality of other feeds in the ration (associative feed effects).

Major factors that influence quality

Six major factors affecting forage quality (not yield), ranked by their impact on forage quality, include maturity, crop species, harvest and storage, environment, soil fertility, and variety. The relative importance of these factors, and some exceptions to the ranking, are described as follows.

Figure 1. Maturation of plant cell walls.

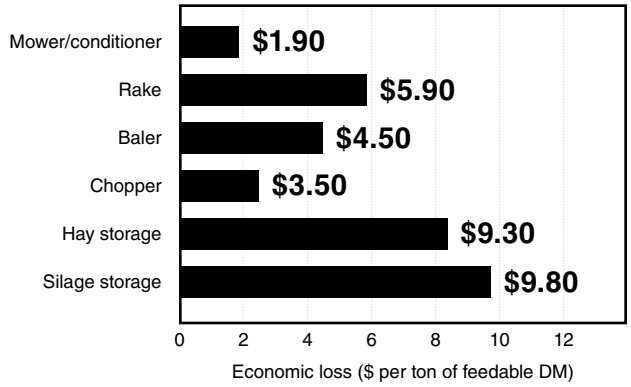


1. Maturity (harvest date). Maturity is the most important factor affecting forage quality. Forage quality is never static; plants continually change in forage quality as they mature (Figure 1). As plant cell wall content increases, indigestible lignin accumulates. In fact, forage plant maturity changes so rapidly that it is possible to measure significant declines in forage quality every two or three days.

2. Crop species. Differences in forage quality between grasses and legumes can be very large. The protein content of legumes is typically much higher than that of grasses, and legume fiber tends to digest faster than grass fiber, allowing the ruminant to eat more of the legume.

3. Harvest and storage. Improper harvest techniques can seriously reduce forage quality, primarily through the loss of leaves. Storing a hay crop at an incorrect moisture content or improper ensiling of a forage crop can dramatically lower its quality. Estimated average economic losses during harvest and storage are shown in Figure 2.

Figure 2. Economic value of harvest and storage losses of alfalfa. (Adapted from D. R. Buckmaster. 1990. Forage Losses Equal Economic Losses, So Minimize Them. *Agr. Engr. Fact Sheet, PM-107, The Pennsylvania State University.)*



4 . Environment (climate). Moisture, temperature, and the amount of sunlight influence forage quality. Rain damage is very destructive to forage quality. When bad weather delays harvesting, the forage crop becomes more mature and hence lower in quality. High temperatures may increase lignin accumulation and decrease quality, but drought stress may actually benefit quality by delaying maturity.

5. Soil fertility. Soil fertility affects forage yield much more than it does quality. While it is possible to produce high-quality forage on poor, unproductive soils, it is generally very difficult to produce high yields of high-quality forage with an unproductive soil resource. Proper soil phosphorus (P) and potassium (K) levels help keep desirable legumes in a mixed seeding and also reduce weed problems. It is necessary to balance soil fertility to avoid mineral imbalances in ruminants. Low soil fertility, as well as very high fertility, has resulted in reduced forage quality.

6. Variety (cultivar). After decades of breeding forages for yield and persistence, attention has recently been focused on developing or identifying varieties with improved quality. Variety or cultivar can affect forage quality, but not as greatly as the other five factors. In alfalfa, selection for improved quality is underway by most commercial companies, and several U.S. firms have initiated selection in corn silage hybrids for improved forage quality.

Other factors influencing quality

Several lesser factors also can influence forage quality. Weeds can negatively affect quality, especially in the case of noxious weeds. Insect pests can lower forage quality, particularly if they cause significant leaf loss. Plant diseases can affect quality when they result in a shift in the species present in the field and when they promote leaf senescence. Insects and diseases generally have their greatest impact on yield and persistence of forages.

Exceptions to the ranking

Forage crops that accumulate a significant quantity of grain may increase slightly in overall quality with maturity as grain content increases in the plant. Some species contain anti-quality factors that can lower animal performance. Variety can become the most important forage quality factor in cases where varieties are developed to significantly reduce or eliminate species anti-quality factors, as in low-alkaloid varieties of reed canarygrass. Harvest and storage of a forage crop at a moisture content leading to spontaneous combustion would plainly become a most important factor. Or, if prolonged flooding or drought threatens a forage crop, environment becomes as important as any of the other factors. Certain soil fertility conditions, such as a very low pH, could eliminate alfalfa from a mixed seeding, thereby changing the species composition of the stand and greatly diminishing stand quality.

SIGNIFICANCE OF THE RANKED FACTORS

All of the ranked factors mentioned earlier can be controlled to some extent through proper management. For example, maturity can be controlled by adjusting harvest dates. The highest quality species that fit the available soil resources should be chosen. Drying agents and preservations may help to avoid rain-damaged forage. Soil testing can identify optimum lime and fertilizer additions. Although variety selection is very important for yield and persistence, it is of relatively less value to forage quality.

Attempts are being made to modify alfalfa plant composition and leaf-to-stem ratio through breeding, as with the multileaf alfalfas. Chemical analyses are the selection criteria. Several alfalfa trials throughout the United States, including Pennsylvania, now include forage quality in their evaluation of new varieties. At a given trial site, all varieties are harvested on the same date and then evaluated for forage quality. Any differences in maturity among varieties could influence the ranking of those varieties (Table 1). In other words, some of the reported differences in forage quality between varieties may only be reflecting that they were harvested and compared at different maturities. Keep in mind that maturity is the most important factor influencing forage quality.

Table 1. Relationship between net energy of lactation (NE_L) and relative maturity (mean stage by count, MSC) for several varieties in an Indiana alfalfa variety trial.

Variety	NE_L Mcal/lb	Maturity stage[a]
Vernal	0.71	2.7
Multileaf-A[b]	0.75	3.2
Multileaf-B[b]	0.75	2.4
High quality-A	0.77	1.4
High yield-A[c]	0.70	3.2
High yield-B[c]	0.70	3.3

a. The higher the maturity stage number, the more mature the alfalfa. A stage reading of 3.0 is at an early flower stage.

b. In the trial, Multileaf-A and -B were selected for the multileaf trait.

c. High quality-A was selected for high quality. High yield-A and -B produced two of the highest yields of 44 varieties tested in the trial.

Selection for forage quality in corn silage is now being done, and it is likely that many commercial companies will be promoting hybrids on this basis as well. Preliminary studies at Cornell University, Michigan State University, and the University of Idaho indicate that there is a range in overall silage quality among hybrids. It may be possible to breed for higher stover quality while maintaining a high grain-stover ratio, and develop a silage hybrid with overall higher digestibility. As with alfalfa, selection may be based on chemical in vitro analyses, with little or no actual animal performance data to back up forage-quality claims. This means that varieties ultimately will be compared for animal performance on the farm by the forage producer. Claims of improved forage quality may be added only after those varieties excel in animal performance tests.

WHAT DETERMINES QUALITY?

Plant composition

All forage plants are composed of cells having fibrous cell walls for support and protection. Contained within the cells are several soluble compounds, most of which are highly digestible (Figure 1). Since cell wall material is the primary constituent of forages, one of the main objectives of forage analysis is to characterize the cell wall fiber.

Plant fiber has three major components: cellulose, hemicellulose, and lignin. Cellulose and hemicellulose are digestible to some extent by ruminants. Ruminants can convert these fiber components to energy because the rumen provides the correct environment for bacteria and other microorganisms that actually break down the fiber. Lignin is indigestible and thus cannot be used by ruminants for energy.

Plant morphology

Both grasses and legumes have two main plant parts, leaf and stem. As a structural component of the plant, stems typically contain more fiber for support. Leaves, on the other hand, provide a means for capture and utilization of energy from sunlight and tend to be lower in fiber content than stems. Given the large difference between the digestible fiber of stems and leaves, the proportion of leaf to stem in a given forage plant relates directly to its forage quality.

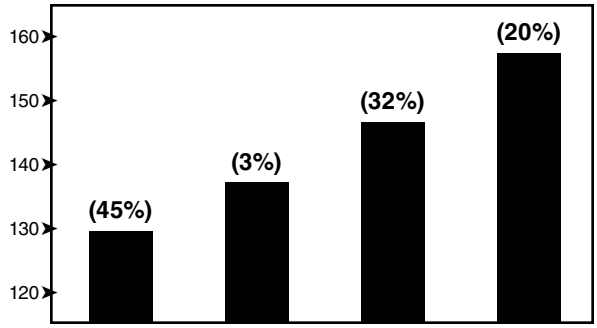
HOW IS QUALITY DETERMINED?

Physical appraisal

Appraisal of a forage based on sight, smell, and touch can provide some general information, but chemical analyses are needed to assess the economic potential of the forage.

At a recent forage meeting, approximately 80 forage producers and industry people were asked to rank four bales of hay by a visual appraisal of their forage quality. The hay ranged from pure alfalfa to an alfalfa-grass mix. An objective quality evaluation of the same bales, based on relative feed value (RFV), found considerable differences among them. There was no consistent pattern in the ratings by individuals, but, in fact, the bale judged best on the basis of appearance had the lowest RFV of the four (Figure 3). Clearly, objective forage analysis is required.

Figure 3. Visual appraisal versus chemical (RFV) ranking of alfalfa and alfalfa-grass hay bales. Percentages are first-place rankings by visual appraisal for each bale.



Chemical analysis

The Van Soest Fiber Analysis System separates feeds into distinct fractions that relate to their nutritive value. Neutral detergent fiber (NDF) consists of the total fiber in the forage and relates negatively to forage intake by ruminants. Acid detergent fiber (ADF) is composed of highly indigestible fiber and relates negatively to forage digestibility. Total nitrogen concentration in the forage (usually expressed as crude protein) is also a useful measure since adequate intake of nitrogen is essential for animal productivity.

Forage laboratories analyze samples for NDF, ADF, and total nitrogen. It is also possible to accurately estimate these components using near infrared reflectance spectroscopy (NIRS). Other estimates of forage quality, such as total digestible nutrients (TDN), net energy of lactation (NEL), and relative feed value (RFV), are derived from mathematical manipulations of NDF and ADF values.

Proper sampling

Clearly, forage quality can be extremely variable and, as in soil testing, proper sampling technique is essential. Without a representative sample, the results from a laboratory analysis are useless. When an alfalfa-orchardgrass hay bale was sampled correctly with a coring device and compared with a grab sample taken from the same bale, their analyses differed considerably (Table 2). A University of Minnesota study showed a large range in quality in a single load of baled hay where NDF values ranged from 34 to 54 percent among individual bales. Good sampling technique, therefore, must involve using the proper sampling equipment and taking an appropriate number of subsamples.

Table 2. Alfalfa-orchardgrass hay bale sampled by two methods.

	Sampling method	
Constituent	**Cored**	**Grab**
Crude protein (%)	16	13
Neutral detergent fiber (%)	56	63
Acid detergent fiber (%)	37	42
Net energy of lactation (Mcal/lb)	0.56	0.49

WHAT IS QUALITY FORAGE WORTH?

The value of high-quality forage in a balanced ration is evident in Table 3. When three hays of low, medium, and high quality are used with corn silage and a mixed feed grain to balance a ration, total feed cost for the high-quality hay ratio is $0.11 less per cow per day than the medium-quality hay ration. Income over grain cost is $0.45 more per cow per day for the high-quality hay ration than for the medium-quality hay. For 100 cows over a year, this difference is greater than $16,000. Low-quality hay does not allow an animal to consume enough digestible energy to be highly productive. A hay of lower quality than the three hays in Table 3 would substantially depress the performance of high-producing dairy cows.

Table 3. What is forage quality worth?

Forage type	Low quality hay	Medium quality hay	High quality hay
Hay composition			
Crude protein (%)	12	15	18
Net energy of lactation (Mcal/lb)	0.51	0.58	0.65
Balanced ration			
Hay (lb)	13	14	17
Corn silage (lb)	33	37	44
Grain (lb[a])	25	22	17
Feed costs			
Hay ($/ton)	70	85	100
Silage ($/ton)	24	24	24
Grain ($/ton)	180	180	180
Total feed cost ($)	**3.11**	**3.02**	**2.91**
Income over grain (IOG) ($)	**4.35**	**4.62**	**5.07**
IOG x 100 cows x 365 days ($)	**158,775**	**168,630**	**185,055**

Note: Assumes second-lactation, 1,350-lb cow producing 60 lb milk/day containing 4% milk fat with a milk price of $11.00/cwt. Adapted from the *Forage Production Manual for the Pro-Dairy Program*. Cornell University, Ithaca NY 14853.

a. Grain is a mixed dairy feed.

KEEPING QUALITY IN PERSPECTIVE

If you want to produce high-quality forage, keep in mind the ranking of quality factors and their relative contribution to quality. While all six factors described are important, using high-quality varieties will be advantageous only when the other five factors are operant. Quantity (yield) of forage is also a major consideration. Evaluate your total forage requirements, and then select the crop and the appropriate acreage of that crop that best meet the needs of the group or groups of animals to be fed. It ultimately comes down to economics; high-quality forage can help keep farmers in the dairy business.

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