EVOLVING FORAGE QUALITY CONCEPTS

Dr. Dan Undersander
Forage Research and Extension Agronomist
University of Wisconsin

As we begin our discussion of forage quality concepts, we should remember why we are measuring forage quality in feedstuffs.

The first reason for measuring forage quality is to balance rations to optimize animal growth, or production of meat or milk. This generally means estimating two parameters: a) estimates of available (digestible) energy or nutrient and b) estimates of intake. Here we must be aware that the world is changing and what was good enough 20 years ago is not good enough today. As production levels of milk, in particular, have risen, properly balanced rations have become more important than ever before. These higher production levels also mean that we are pushing the milking dairy cow to the edge where factors, not previously of great concern, can now cause the cow to develop health problems and result in lost production. Thus, when balancing rations, we are not only attempting to optimize animal production but also to avoid animal health problems by such considerations as feeding adequate fiber and avoiding excess soluble protein.

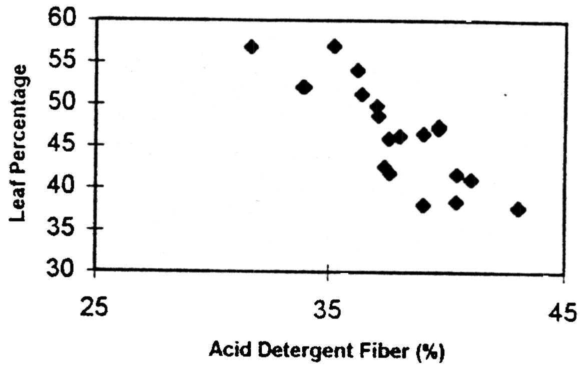
The second reason for forage analysis is to develop least cost rations for the animals we are feeding. The more accurately we can characterize the availability of energy, minerals and other metabolites in the forage, the better we can match forage to the appropriate animal category and the more we can match least cost grain and other supplements to the forage being fed.

The third reason for forage analysis is to determine the value of hay for marketing. There is value in hay quality when being fed and there is cost to the production of quality hay, therefore the seller should share in the value of quality hay. This value of quality is reflected in many hay markets. However, it is important that the basis of quality pricing have foundation in animal feeding. There is the tendency in marketing to think that more is better, i.e. 27% crude protein alfalfa is better than 24% crude protein, which is not always the case as far as the animal is concerned. Pricing considerations for hay quality should be based on animal responses.

In the past, and still in some regions of the U.S., hay was/is evaluated visually. Farmers would look for green color, leafiness, and texture. This evaluation can certainly separate hay into rough categories of good, average, and bad. But certainly is not adequate for determining the feeding value of the hay. While surveys have indicated that the single most important characteristic for rejection of hay lots on delivery is color, all nutritionists agree that color has no relationship to the nutritional value of the hay beyond determinations of spoilage. First, green color appears differently to different individuals. Second, the greenness of a hay depends on the light under which the hay is viewed, i.e. the color would appear different on a cloudy day than on a sunny day or in a barn vs outside. The color relates to the chlorophyll content, which does not relate to any animal performance parameter.

Visual rating of leafiness, too, can be in indication of quality hay. But this too can be misleading because, under best conditions, around 50% of alfalfa is stem and stem digestibility can vary greatly and then affect the overall nutritional value of the hay. As shown in figure 1, samples with similar leaf percentages can range 7 to 8% in acid detergent fiber.

Fig 1. Effect of Leaf Percentage on ADF Content



Texture is usually a secondary 'visual' characteristic. It certainly has some effect on the percentage of refusal in the feed bunk; though this becomes questionable if the hay is mixed in a Total Mixed Ration. Texture has little relationship to nutritional quality of the forage. Thus none of the visual characteristics have a significant relationship to the value of the hay to the animal being fed.

The best way to determine the value of a forage is to do a feeding trial where, over a period of 3 to 4 weeks, forage is weighed and fed to several animals of the desired class (i.e. milking cow, stocker, or growing animal), and manure and urine are collected and weighed. The dry weight of the manure divided by the dry weight of the forage fed is the apparent digestibility of the forage. Obviously this is too time consuming and expensive for determining nutritive value of individual forages. However, it is important to remember that all other forage analysis values we use are an attempt to estimate values derived from such feeding trials.

Among the first estimate of forage nutritive value was the crude fiber system developed in the 1890's as an attempt to separate fiber from more readily digestible portions of the forage. The problem with this system, and the modified crude fiber system, is that varying amounts of fiber fractions were dissolved out in the non-fiber fraction. Thus, there was no structural or biochemical relationship to the crude fiber value. Since each cell wall fraction digests in the rumen at a different rate and to a different extent, the crude fiber might correlate well with digestibility of a similar sample type and from a range of environmental conditions, but would not predict animal performance accurately from samples outside the range of conditions used to develop the relationship.

The next advance in fiber analysis was the development of the detergent fiber system by Goering and Van Soest in the 1970. This system estimated two fiber fractions in forage. Neutral detergent fiber (NDF) was related to the total cell wall and included hemicellulose, cellulose, lignin and ash. The term has been used it estimate how much an animal will consume (intake). The second fraction, acid detergent fiber (ADF), contained all of the above fractions except hemicellulose. Hemicellulose is rapidly digestible in the rumen. Therefore the fiber fractions remaining in ADF are often correlated with digestibility and used to calculate total digestible nutrients (TDN). This relationship assumes that all cell walls digest at the same rate. While the correlation has historically been reasonably good within a forage species, the relationship changes as forage changes and, as we are finding with higher producing herds, the relationship also varies among years, indicating an environmental effect on digestibility of the cell wall.

TDN and net energy of lactation (NE_L) are simply calculated values that are derived from regressions of the fiber analysis with animal performance data. Thus each researcher with a different data set gets a slightly different equation as shown in table 1. The different TDN equations mean that the same forage would have different TDN values depending on which state/regional equation was used to calculate TDN.

A number of researchers have used rumen microbes to determine digestibility as an estimate of forage quality. The advantage of this is that rumen microbes are actually digesting the forage. Digestibility may be determined by adding forage and rumen microbes to a test tube which is incubated for a fixed time period (*in vitro*)or putting the forage in a nylon bag and suspending the bag in the rumen of a cow for a fixed time (*in situ* or *in sachu*). Results of this system have higher correlations with animal performance than fiber analysis because it detects variations in fiber digestion that fiber analysis does not detect (figure 2). However this system is seldom used outside of research because of the expense and problems with run to run (and, therefore, laboratory to laboratory) variation in results. There is an additional problem in that digestibility is related to the rumen retention time. Animals at higher feed levels, such as milking cows, have shorter rumen retention times than animals at lower feed levels, such as growing heifers. Thus digestibility would be different for a milking cow than a growing heifer.

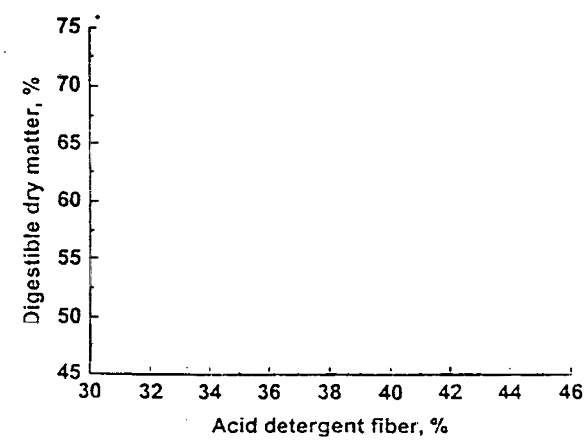


Fig 2. Relation of Acid Detergent Fiber to Digestibility
From Swanson and Kercher, 1996

Now the potential exists to solve most of these problems through use of near infrared reflectance spectroscopy (NIRS). Near infrared reflectance spectroscopy reads organic bonds very accurately. Thus, chemical components, such as protein, starch, cellulose, etc, can be determined with greater than 98% agreement with wet chemistry. It is widely used in the grain industry to determine moisture and protein at grain terminals so that sellers can have an analysis at point and time of sale. This technology is also very applicable to forage analysis, though such applications are more difficult, because we are generally looking at multiple chemical constituents, i.e. fiber, rather than a single component, such as protein or starch. The second problem is that early NIRS instruments and versions of software caused instrument to instrument variation in prediction from the same sample with the same equations. This problem has been solved by standardization of instruments for those laboratories with newer NIRS instruments and will to

Table 1. Energy Prediction Equations Regions of the United States

Prediction Equations from Midwest

Legume and Grass Forages

%DDM = 88.9 - (0.779 x ADF)[a]

Corn Silage

%TDN = 87.84 - (.70 x ADF)[b]

TDN conversion to NE_L

NE_L (Mcal/lb) = (TDN x .01114) - 0.054[c]

Prediction equations from Pennsylvania State [d]

Legumes

%TDN = 4.898 + (89.796 x NE_L)
ENE (Mcal/100 lb) = NE_L x 82.6
NE_L (Mcal/lb) = 1.044 - (0.0119 x ADF)

Mixed Forages

%TDN = 4.898 + (89.796 x NE_L)
ENE (Mcal/100 lb) = NE_L x 82.6
NE_L (Mcal/lb) = 1.0876 - (0.0127 x ADF)

Grasses

%TDN = 4.898 + (89.796 x NE_L)
ENE (Mcal/100 lb) = NE_L x 82.6
NE_L (Mcal/lb) = 1.0876 - (0.0127 x ADF)

Corn Silage

%TDN = 31.4 + (53.1 x NE_L)
ENE (Mcal/100 lb) = NE_L x 82.6
NE_L (Mcal/lb) = 1.044 - (0.0124 x ADF)

Prediction Equations from Western Region [e]

Alfalfa

%TDN = 82.38 - (0.7515 x ADF)
NE_L (Mcal/lb) = 0.8611 - (0.00835 x ADF)

Prediction Equations from New York State

Grasses

%TDN = 34.9 + (53.1 x NE_L)
ENE (Mcal/lb) = NE_L x 0.826
NE_L (Mcal/lb) = 1.085 - (0.0150 x ADF)

Legumes

%TDN = 29.8 + (53.1 x NE_L)
ENE (Mcal/lb) = NE_L x 0.826
NE_L (Mcal/lb) = 1.044 - (0.0123 x ADF)

Mixed Forages

%TDN = 32.4 + (53.1 x NE_L)
ENE (Mcal/lb) = NE_L x 0.826
NE_L (Mcal/lb) = 1.044 - (0.0131 x ADF)

Corn Silage

%TDN = 31.4 + (53.1 x NE_L)
ENE (Mcal/lb) = NE_L x 0.826
NE_L (Mcal/lb) = 0.94 - (0.008 x ADF)

[a] Source: Rohweder, Barnes and Jorgensen, J. Anim. Sci. 68:403
[b] Source: Schmidt *et al.*, Agron. J. 68:403
[c] Source: NRC, Dairy Update, 1989
[d] Source: Proceedings 41st Semiannual Meeting, 1981. Am. Feed Manufacturers Association. Lexington, Ky. p16-17.
[e] Source: Bath, Donald L. and Vern L. Marble. 1989. Testing Alfalfa for Its Feeding Value. Univ of CA. Cooperative Extension. Leaflet 21457. (WREP 109).

Table 2. Factors used in Ration Balancing

Dry Matter	Nitrogen Free Extracts	Magnesium
ADF	Starch	Sulfur
NDF	Fat	Calcium
Crude Protein	Vitamins	Ash
Digestible Protein	TDN	Amino Acids
UIP	Digestibility	Lysine
Fiber	NE_M	Threonine
Cellulose	NE_L	Methionine
Lignin	Phosphorus	
Pectin	Potassium	