ALFALFA PRODUCERS: DO YOU REALLY KNOW HOW GOOD YOUR ALFALFA IS?
FORAGE ANALYSIS: IMPORTANCE AND INTERPRETATION

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INTRODUCTION

Forages make up over 75% of the diet of all cattle and are the basis of cow-calf industry in the midwest. However, a recent survey of over 1000 livestock producers in Missouri revealed that only 5.6% had ever had their hay tested. They gave several reasons for why they had not tested hay (Table 1). By a large margin, the greatest reason for not testing was that they did not see a need. This fact highlights the purpose of this paper and presentation at the 10th Annual Kentucky Alfalfa Conference. This paper will explain the terms used in forage quality analyses, the use of Near Infrared Reflectance Spectroscopy (NIR) in rapidly testing forage quality, and the interpretation of forage analysis results.

Table 1. Reasons given and frequency of response for not testing forage quality of hay.¹

<table>
<thead>
<tr>
<th>Reason</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don’t see a need</td>
<td>43.0</td>
</tr>
<tr>
<td>Too inconvenient</td>
<td>28.0</td>
</tr>
<tr>
<td>Other</td>
<td>12.0</td>
</tr>
<tr>
<td>Too expensive</td>
<td>8.7</td>
</tr>
<tr>
<td>Don’t have time</td>
<td>7.9</td>
</tr>
<tr>
<td>No answer</td>
<td>0.3</td>
</tr>
</tbody>
</table>

¹From a 1988 survey of Missouri grassland producers conducted jointly by the Missouri Forage and Grassland Council, USDA Soil Conservation Service, the University of Missouri - Columbia, the Agricultural Research Service, and the National Agricultural Statistics Service.

WHY TEST FORAGES

It would be unthinkable to buy or feed energy or protein supplements without checking and knowing the feed analysis. Yet millions of pounds of alfalfa hay are bought and fed each year without an analysis, for the reasons listed above. But look at some of the reasons for testing forages. If the alfalfa is potentially for sale, having a forage analysis from a certified laboratory will help negotiate the top price possible. In fact, hay marketing is one of the last areas where a producer can have an active role in setting the price for his or her product. For commodities such as corn or soybeans, the
price is set at the elevator with little possibility for compensation for a high quality product. For hay that will remain on the farm and be fed, testing will allow the most efficient use of the forage and will keep the amount spent for supplemental energy or protein at a minimum. With a current forage analysis on all the major hay lots to be fed, a producer can develop an efficient, lowest possible cost winter feeding program for their cattle.

**FORAGE QUALITY TERMS**

The best place to start in describing forage quality terms is with ‘forage quality’ itself. Forage quality has been defined as the ability of a forage to produce a desired level of animal performance when consumed. Therefore, for the cow/calf producer, forage quality is the ability of a forage to supply nutrients for milk production, cow condition maintenance, heifer development, and calf gain.

Forage quality analysis report forms vary from laboratory to laboratory, but usually contain information on moisture (%), dry matter (DM, %), crude protein (CP, %), heat damaged protein (HDP, %), acid detergent fiber (ADF, %), neutral detergent fiber (NDF, %), total digestible nutrients (TDN, %), and net energy calculations for lactation (NE_L, mcal/lb), maintenance (NE_M, mcal/lb), and gain (NE_G, mcal/lb) (Figure 1). The analysis form for the Mizzou mobile forage laboratory also contains an estimation of relative feed value (RFV).

![Figure 1. Forage test report from a mobile NIR forage laboratory.](image)

There are two columns of information in Fig. 1, labelled ‘As Fed Basis’ and ‘Dry Matter Basis’. The as fed numbers reflect nutrient concentrations in the forage as it was received in the forage lab, including all water present. Because water dilutes the concentrations of all other nutrients, all numbers in the as fed column will be less than the dry matter column, with the exception of moisture. Use the as fed values when figuring what weight of actual hay will be needed to supply a given amount of a
nutrient. For example, the hay in Fig. 1 contains 16.7% crude protein on an as fed basis. If a producer wanted to grind enough hay to provide 1000 lb. of protein for a winter feed mix, he/she would need to grind 5988 lb. of hay \((1000/0.167 = 5988)\). The dry matter column is the concentration of a given nutrient with all water removed. Because the dry matter numbers are higher and moisture contents in hay vary, communication about the quality of hay is often done using dry matter numbers. A word of caution here. Buying hay on dry matter analysis alone can be costly. For example, a dairyman in a neighboring state bought a truckload of Colorado alfalfa at a cost of $135 per ton, delivered. The alfalfa had a dry matter crude protein analysis of 23%. However, the hay also contained 25% moisture. Therefore, that producer paid $135 per ton for about 10,000 lb of water present in the hay, which is pretty expensive water. A question about the moisture content might have led to a lower price for the hay per fresh ton.

Moisture, expressed as percent, is the water present in the forage analyzed. Dry matter (DM), on the other hand is the percentage of the forage that is not water. Nutrient concentrations in the as fed column can be determined from the dry matter column by multiplying the DM concentration by DM expressed as a decimal. Using the example in Fig. 1, CP (DM basis) was 19.2%, and DM was 86.7%. Therefore the 'as fed' CP concentration was 19.2 X 0.867 or 16.7%.

Crude protein (CP) is a mixture of true protein and non-protein nitrogen, and is a measure of a forages ability to meet the protein needs of livestock. It is calculated by measuring the nitrogen concentration and multiplying by 6.25. The 6.25 factor comes from the fact that true protein in forages contains about 16% nitrogen, meaning that there is about 6.25 lb. of total protein for each pound of nitrogen present. Most protein in forages is true protein, with exceptions for nitrate accumulating summer annual grasses such as sudangrass and pearl millet. Although high protein forages are often high in energy, CP content is of little value in determining energy content. Since protein is one of the most costly supplements for beef cows, high protein forages such as alfalfa are desirable.

Heat Dam. Protein (HDP) or heat damaged protein is an estimate of that protein that is associated with the indigestible fiber of the forage. This characteristic is estimated by measuring the nitrogen present in the indigestible part of the cell wall and multiplying by 6.25. The ‘heat damage’ name comes from the binding of protein to fiber that occurs in hay or silage that goes through excessive heating. This ‘bound protein’ is indigestible and not available to the animal. Hay or silage that has heated extensively is said to have caramelized and will have a tobacco odor. Although this hay is often extremely palatable to livestock, little of the protein is utilized. In extreme cases, the protein digestibility can approach zero. If the HDP is less than 10% of the CP value, then heating during storage was not excessive. Since the cell wall is a living part of the plant, even fresh material which has not gone through heating will have some nitrogen associated with the fiber and will have a HDP value.

Acid Det. Fiber (ADF) or acid detergent fiber is the percentage of highly indigestible plant material present in a forage. It contains cellulose, lignin, and silica. Acid detergent fiber has been found to be a useful predictor of energy and digestibility in forages. Low ADF values mean higher energy value and digestibility. In fact, all of the
Energy estimates presently used in forage testing are calculated from ADF alone. Therefore, low ADF values are desirable.

Neut. Det. Fiber (NDF) or neutral detergent fiber represents all of the structural or cell wall material in the forage. Unlike ADF, NDF is partially available or digestible by livestock. The NDF of a forage is inversely related to the amount that a cow or calf is able to consume, meaning that forages with low NDF will have higher intakes than those with high NDF. In general, legumes tend to have lower NDF values than grasses. Research from the USDA-ARS Dairy Laboratory in Madison, Wisconsin suggests that the relationship between NDF and intake for lactating dairy cows is:

\[
\text{Intake (\% of Body wt.)} = \frac{120}{\text{NDF(\%)}} \quad \text{(Mertens, 1982; Mertens, 1985)}.
\]

Therefore, a forage which is 40% NDF will be consumed at 3% of the body weight of the consuming dairy animal. Since beef cows are generally at a lower level of performance and intake than dairy cows, their intake will probably be slightly lower. A suggested formula for estimating intake for lactating beef cows is:

\[
\text{Intake (\% of Body wt.)} = \frac{100}{\text{NDF(\%)}}.
\]

These formulas express estimates of the amount an animal will eat when forage is the only feed. Keep in mind that several other factors also influence intake, including weather, endophyte infection level in tall fescue, previous nutrition level, and anti-quality factors in the forage.

Total digestible nutrients (TDN) is the percentage of digestible material in a forage. Total digestible nutrients are calculated from ADF and express the differences in digestible material between forages. (Note that TDN is approximately equal to NE\text{L} or NE\text{M} multiplied by 100). The term itself is a hold-over from the days of proximate analysis where the digestible components of crude fiber, crude protein, fat, and nitrogen-free extract were summed to derive TDN. The problems with the proximate analysis system of roughage analysis are well illustrated by the following example. Morrison (1951), using the proximate system of forage analysis, reported the TDN of average alfalfa hay was 50.3%; average grass hay, 44 to 47%; and oat straw, 44.7%. Morrison, in comparing the old TDN and proximate analysis to newer net energy estimations, stated, "No experienced stockman believes that oat straw is really worth over four-fifths as much as good alfalfa hay, or nearly as much as average grass hay, for stock being fed for production."

Net energy of lactation (NE\text{L}) and maintenance (NE\text{M}) are expressions of energy value of forage (in megacalories(mcal) per lb.) and refer to its ability to meet the maintenance requirements of dairy and beef cattle. Like TDN, NE\text{L} and NE\text{M} are calculated solely from ADF. The lactation and maintenance terms are only different in name; dairy producers are used to using NE\text{L} to balance rations, and beef producers are more used to using NE\text{M}. For most hays, haylages, and silages, the net energy value for lactation will be very nearly equal in number to the net energy for maintenance.
Net energy for gain (NE\textsubscript{g}) is the amount of energy in a forage available to produce weight gain. The value of NE\textsubscript{g} is always lower than NE\textsubscript{l} or NE\textsubscript{m} for a given forage because the forage is used less efficiently for gain than it is for maintenance.

Relative feed value (RFV) is used to compare one forage to another on an energy basis. It is derived by taking into account the digestibility (calculated from ADF) and the potential intake (calculated from NDF) of a given forage. For comparison purposes, the RFV of mature, full bloom alfalfa was set at 100. The alfalfa in Fig. 1 has an RFV of 124.4; therefore it contains 24.4% more energy than mature alfalfa.

**USE OF NIR TECHNOLOGY IN FORAGE TESTING**

A new and exciting means of testing forages is the use of the near infrared reflectance (NIR) spectrophotometer. The NIR unit allows the estimation of major forage quality measures (CP, ADF, NDF, Moisture, DM, and some minerals) much more quickly and rapidly than conventional wet chemistry techniques. Basically, an NIR forage tester scans a specially prepared forage sample with near infrared radiation, stores the light that is reflected off the sample, and compares that information to the light information from a set of hay samples (with known forage analyses) in the memory of a computer. From this comparison, the NIR instrument can predict the forage quality of a sample in only about 10 to 20 minutes, including the sample preparation time, depending on the initial sample moisture. The instrument and computer can be housed inside a specially modified van, resulting in a mobile forage testing laboratory. This mobile NIR technology has been successfully used in several midwestern states to promote hay testing, the use of ration balancing techniques to determine how forages might be more efficiently fed, and the marketing of quality tested hay.

The accuracy and repeatability of results with NIR technology is as good as and often better than comparable wet chemistry laboratories. The primary reason for this is that the NIR is completely based on information from a certified forage analysis laboratory using traditional wet chemistry methods. Also, because there are fewer steps and procedures using NIR, there is much less opportunity for human error.

**INTERPRETATION OF FORAGE ANALYSIS RESULTS**

There are three major steps in interpreting forage analysis results. First, determine the class of animals to which the forage will be fed. Second, determine the nutrient requirements for the animal to reach the desired level of performance. Thirdly, evaluate the forage’s ability to supply the necessary nutrients.

The best way to learn how to interpret forage analyses is with concrete examples. For the following discussion, a few representative forages have been analyzed in a certified NIR forage testing laboratory (Table 2). These will be evaluated according to their ability to feed three types of livestock: a)1100 lb. dry cows, b)1100 lb. cows in early lactation (average milking ability), and c)500 lb. medium frame steers gaining 1.5 lb./day. The major nutritional requirements for these livestock are found in Table 3.
Table 2. Summary of NIR analyses on selected forages.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Bale Type</th>
<th>Storage</th>
<th>CP</th>
<th>TDN</th>
<th>HDP</th>
<th>NEG</th>
<th>RFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass setaside hay</td>
<td>Large</td>
<td>Outside</td>
<td>10.9</td>
<td>50.5</td>
<td>0.7</td>
<td>0.20</td>
<td>99</td>
</tr>
<tr>
<td>Oat hay</td>
<td>Large</td>
<td>Outside</td>
<td>14.1</td>
<td>60.5</td>
<td>0.9</td>
<td>0.34</td>
<td>99</td>
</tr>
<tr>
<td>Foxtail hay</td>
<td>Large</td>
<td>Outside</td>
<td>11.5</td>
<td>53.8</td>
<td>0.9</td>
<td>0.25</td>
<td>75</td>
</tr>
<tr>
<td>Alfalfa/Tim/Og hay</td>
<td>Large</td>
<td>Outside</td>
<td>12.0</td>
<td>56.1</td>
<td>0.9</td>
<td>0.28</td>
<td>96</td>
</tr>
<tr>
<td>Alfalfa,1st cut hay</td>
<td>Small</td>
<td>Inside</td>
<td>13.7</td>
<td>54.2</td>
<td>0.9</td>
<td>0.25</td>
<td>102</td>
</tr>
<tr>
<td>Alfalfa,2nd cut hay</td>
<td>Large</td>
<td>Outside</td>
<td>18.9</td>
<td>57.5</td>
<td>1.1</td>
<td>0.30</td>
<td>108</td>
</tr>
<tr>
<td>Alfalfa,3rd cut hay</td>
<td>Large</td>
<td>Inside</td>
<td>19.2</td>
<td>61.2</td>
<td>1.1</td>
<td>0.35</td>
<td>124</td>
</tr>
<tr>
<td>Alfalfa/Og haylage</td>
<td>-----</td>
<td>Stave</td>
<td>19.2</td>
<td>53.7</td>
<td>2.4</td>
<td>0.25</td>
<td>100</td>
</tr>
<tr>
<td>Corn silage, 3 bu/A</td>
<td>-----</td>
<td>Bag</td>
<td>9.9</td>
<td>69.1</td>
<td>0.0</td>
<td>0.46</td>
<td>106</td>
</tr>
<tr>
<td>Corn silage, 10 bu/A</td>
<td>-----</td>
<td>Bag</td>
<td>9.9</td>
<td>68.1</td>
<td>0.0</td>
<td>0.44</td>
<td>101</td>
</tr>
</tbody>
</table>

*Dry matter basis.

Table 3. Selected nutrient requirements of three types of beef cattle.

<table>
<thead>
<tr>
<th>Intake, lb. (max)</th>
<th>1100 lb. Dry Cow</th>
<th>1100 lb. Lact. Cow</th>
<th>500 lb. Steer (1.5 ADG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP,%</td>
<td>7.0</td>
<td>9.4</td>
<td>10.5</td>
</tr>
<tr>
<td>TDN,%</td>
<td>48.8</td>
<td>56.0</td>
<td>63.0</td>
</tr>
<tr>
<td>NE_G, Mcal/lb.</td>
<td>----</td>
<td>----</td>
<td>0.38</td>
</tr>
</tbody>
</table>

The CP requirements for the dry cow (D), lactating cow (L), and steer (S) are 7.0, 9.4, and 10.5%, respectively (Table 3). All of the forages tested were able to meet the CP needs of these selected livestock except for the corn silages (Fig. 2). And these silages were only too low in CP for the growing steer diets. This points out a consistent pattern when balancing forage rations for beef cows, especially. Except when dealing with crop residues, almost all forages contain sufficient CP for dry cows, and many will meet the needs of lactating cows of average milking ability. Since protein supplements are usually the most expensive purchased feed ingredients, knowing the CP content of hay is one of the fastest ways to save money by forage testing.

The TDN requirements for the dry cow, lactating cow, and steer are 48.8, 56.0, and 63 %, respectively (Table 3). In this case, the energy levels of the forages were less sufficient than CP content (Fig. 3). Let’s look at each animal separately. For the dry cow, all forages were able to meet her TDN needs. However, in the case of the lactating cow, only the oat hay (OAT), second and third cutting alfalfas (ALF2, ALF3), and corn silages (CS3, CS10) contained enough energy. Ordinarily, first cutting alfalfa and
alfalfa/orchardgrass haylage would be expected to support this level of performance, (be higher than 58% in TDN). However, there are a couple of reasons why these forages failed. This first cutting alfalfa hay was harvested in July from land released from the CRP. Therefore, it was very mature, stemmy, and low in energy. The alfalfa/orchardgrass haylage is a more confusing case. The CP was 19.2%, and one would expect a much higher TDN concentration than 53.7%. However, the heat damaged protein (HDP) was 2.4%, which is more than one-tenth of the CP (Table 2). This indicates excessive heating during the ensiling process. Undesirable bacteria and fungi generate heat and carbon dioxide from the consumption of available energy from the forage by decomposing microbes. The net result is a loss of dry matter (from carbon dioxide gas loss), an increase in all fiber components, and a lowering of the energy available to ruminants. Oddly enough, CP does not drop much. Remember that CP is calculated by measuring the nitrogen content and multiplying by 6.25. In silage that heats, the microbes convert some of the plant protein into microbial protein. Therefore, little nitrogen is lost compared to energy.

For the growing steers, only the corn silages (CS3, CS10) contained enough energy to maintain their rate of gain at 1.5 lb./day. Feeding any class of animals for weight gain is particularly challenging when forages are the only source of feed. This is due in part to the lower utilization efficiency when producing weight gain. A certain portion of the energy of the forage must go toward meeting the maintenance requirement of the animal. Only after the maintenance requirement is met can the animal begin to gain. Livestock that are growing also have smaller digestive systems and their maximum intake is reduced compared to mature animals (Table 3).

All of the interpretations above are based on each class of livestock consuming the maximum amount of dry matter of each forage for their size and level of performance (Table 3). Be aware that there are several factors influencing the intake of a given forage, including weather, animal health, presence of the endophytic fungus (in tall fescue), etc. Even after the most careful forage testing and ration planning, it always is
important to make sure that the cattle are eating enough of the forage to meet their needs.

One final way to interpret forage analysis reports is by comparing the relative feed values (RFV). Remember that RFV does not have significance in ration balancing, but is a tool to compare different forages based on their estimated digestibility (calculated from ADF) and intake (calculated from NDF, primarily). The RFV scale here is based on 100 being equal to the energy content of mature alfalfa hay. The forages tested for this article range in RFV from 75 to 124 (Table 2). The lowest RFV was for the foxtail hay, indicating that it was cut late. A correct interpretation of the foxtail RFV value of 75 would be that the hay contained 75% of the energy contained in mature alfalfa hay. Notice that the first cutting alfalfa (from released CRP acres) and second cutting alfalfa had very similar RFV's (102 vs. 108). Yet the first cutting alfalfa was much lower in CP. This reinforces the point that RFV is an energy comparison, not a protein comparison.

**SUMMARY**

Forage testing is a good management tool that is under-utilized by most alfalfa producers. New technology such as Near Infrared Reflectance (NIR) spectroscopy is helping to make forage testing more available, more rapid, and less expensive. Although forage testing is not free, the improved sales revenue, efficiencies and feed savings more than make up the cost and trouble expended.

Forage testing should be a priority for every alfalfa producer, for two reasons. First, it allows that producer to reap the benefits of their management efforts by achieving top prices for their cash hay. Secondly, knowing the forage analysis will allow producers to be more intelligent utilizers of the excellent feed quality potential present in alfalfa.
Interpretation of forage results is basically comparing the nutrients available in a given forage to the needs of the class of livestock to be fed. This fact applies whether hay is to be sold or fed, because the cash value of hay is ultimately tied to its ability to produce meat or milk. In forages, energy is the most limiting nutrient, whether for dry, lactating, or growing animals. According to the forages tested for this paper, protein supplementation is seldom needed, except in high milk producing cows and growing animals. Increased profits from forage testing will come from being able to market alfalfa hay at the best possible price as well as more efficient utilization of alfalfa as a supplemental protein and energy source.

REFERENCES

