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Forage Testing - Why, How, and Where

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Forage testing assesses the nutrient composition of forages and permits a producer to develop feeding and marketing strategies. This publication has been developed to inform livestock and/or cash-crop hay producers of the benefits of forage testing. Information on different analytical procedures, terminology, sampling procedures, and the application of results is presented.

Forage Quality

Forage Quality Defined

Since forages are predominantly used by livestock as a source of nutrition, forage quality is an expression of the characteristics that affect consumption, nutritive value, and the resulting animal performance.

Factors Influencing Forage Quality

Since many factors affect forage quality, no single factor can be used to make this prediction. Maturity stage at harvest, forage species and variety, leafiness, harvest and storage conditions, and the presence of pests are important factors that determine quality.

Maturity. As forage plants mature, the concentration of structural carbohydrates and lignin increases. Structural carbohydrates, the plant’s fiber component, include cellulose and hemicellulose. While cellulose and hemicellulose can be partially digested by ruminant livestock and horses, another part of the fiber component, lignin, is not digestible. Research has shown that an increase of one percentage unit of lignin will result in three to four percentage units decrease in digestible dry matter (DDM). As the amount of fiber increases and digestibility decreases, forage consumption is also reduced; therefore, the amount of digestible energy consumed decreases as the forage matures.

Species and variety. Forage quality differences between species and among varieties within a species are generally related to differences in structural carbohydrate concentration, leaf content, or the presence of unsuitable components that affect consumption and digestibility.

Leafiness. Leaves contain more nonstructural carbohydrates and protein than stems. The nonstructural carbohydrates, which include plant sugars and starches, are highly digestible. When forage plants mature, the leaf to stem ratio decreases. Thus, forages with a greater amount of leaves are more likely to be of higher quality.

Harvest and storage conditions. Forage crops decrease in nonstructural carbohydrate concentration and digestible dry matter percentage during the curing process because of plant respiration. Decreases in digestible dry matter can also occur from the leaching of soluble nutrients during rainfall and the physical loss of leaves at harvest. But management techniques that minimize curing time (use of a mower-conditioner, drying agent and/or preservative) can minimize digestible dry matter loss. Just as plant respiration reduces forage quality during curing, similar activity can cause quality changes during storage. If hay with excessive moisture is packaged and stored, mold may develop. Mold-producing organisms generate heat through respiration; the mold and heat reduce consumption as well as protein and dry matter digestibility.

Presence of pests. Diseases, insects, and some weeds have been responsible for reduced forage quality. Particularly noteworthy pests are leaf diseases and high populations of the alfalfa weevil and potato leafhopper.
Forage Testing

Why Conduct Forage Testing?
Forage testing is used to determine nutrient composition and potential animal performance. Once the factors that determine forage quality have been measured, a more accurate ration can be formulated for a specific class of livestock according to nutritional requirements for optimum performance. The significance of forage testing is illustrated in the following example.

In a dairy-feeding trial, two groups of cows were fed different alfalfa rations during a 305-day lactation. The two alfalfa rations fed were two maturity stages, early-bloom and full-bloom. (The nutrient compositions of these forages and their associated milk yields are found in Table 1.) The higher nutritive value of early-bloom alfalfa results in considerably more milk production from cows than does full-bloom alfalfa. The addition of corn silage to both these rations resulted in increased milk yields, but a greater response was observed for cows fed the full-bloom alfalfa. These results clearly indicate the nutritional shortcomings of full-bloom alfalfa in the ration of lactating dairy cattle, especially those rations not properly supplemented.

Forage testing is used to indicate nutrient content of hay, silage, or any other forage fed to livestock. Depending on the livestock class being fed, nutrient content of the forage may be adequate or inadequate for maintenance and production.

Methods of Forage Testing
Several methods of estimating or analytically determining nutrient content of forages have been used for many years. Recently, new forage testing procedures have also been developed. Some methods for determining forage quality include visual appraisal, chemical analysis, near infrared reflectance spectroscopy, plus in vivo and in vitro measurements. Each method has strong and weak points as well as specific uses in forage evaluation.

Visual appraisal. Visual appraisal is the oldest and most widely used forage evaluation method. The term visual appraisal is not limited to the sense of sight; it is also based on texture and odor. Forage appearance is evaluated by color, leafiness, maturity, and the presence of foreign material (mold, dust, and weeds). Texture refers to stem texture and its relationship to maturity stage at harvest.

Since visual appraisal relies heavily on subjective evaluation, it is possible that no two people will evaluate the same forage in the same way. Factors such as the intended use and the evaluator’s past experience can greatly influence the evaluation, and then it becomes very difficult to communicate descriptive terms. Even though visual appraisal is relatively fast, color, texture, and odor do not necessarily relate well to animal performance.

Chemical analysis. A truly meaningful assessment of forage quality requires an evaluation of its chemical makeup. Determination of the chemical components requires laboratory procedures. The chemical analysis of a forage will identify nutritionally

<table>
<thead>
<tr>
<th>Table 1. Differences in Milk Production of Dairy Cows on Different Forage Rations with Different Nutrient Contents.*</th>
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<tbody>
<tr>
<td><strong>Variable</strong></td>
</tr>
<tr>
<td>Crude protein, %</td>
</tr>
<tr>
<td>Lignin, %</td>
</tr>
<tr>
<td>Acid detergent fiber, %</td>
</tr>
<tr>
<td>Digestible dry matter, %</td>
</tr>
<tr>
<td>Milk yield (alfalfa only), lb.</td>
</tr>
<tr>
<td>Milk yield (alfalfa plus corn silage), lb.</td>
</tr>
</tbody>
</table>

*University of Minnesota
strong and weak points; proper supplementation can then be made to ensure optimum animal performance. The main limitation of this method of forage testing is slow turnaround time and expense. These common complaints indicate the need for a method of forage analysis that would allow for more rapid return of results to the producer at a lower cost.

Near Infrared Reflectance Spectroscopy (NIRS). The use of NIRS to determine the major chemical constituents in forages is relatively new. This computerized method of forage testing, which is based upon accurate chemical analyses, can solve the slow turnaround problem of chemical analysis. The forage can be analyzed in less than ten minutes using NIRS, compared to hours and even days for conventional chemical methods. The major organic components of forage have specific absorption characteristics in the near-infrared region of the spectrum. Thus, their identification and measurement are possible through mathematical relationships.

In vivo and in vitro measurements. In vivo and in vitro measurements determine the digestibility of dry matter and fiber. Due to the cost and the length of time required to perform these procedures, they are not used in routine analysis of forages for on-farm use. They are, however, used extensively by scientists for evaluation of forage quality. The main difference between these procedures is that in vivo procedures are conducted using test animals; in vitro procedures are performed in test tubes that simulate the rumen.

Components of Forages
A well-equipped forage testing laboratory can analyze forages for many components, but more tests will be required if a more complete analysis is desired. However, additional tests can increase costs and delay return of the results to the producer. Usually forages need only be analyzed for the nutritional information that will be useful to the producer. Components that should be tested on a routine basis are dry matter, crude protein, acid detergent fiber, and neutral detergent fiber.

Definitions of Common Forage Analysis Terms:

Dry matter (DM) is the percentage of the forage that is not water. Nutrient requirements of animals are expressed on a DM basis.

Crude protein (CP) is the total amount of nitrogen contained in a forage; percent nitrogen is multiplied by 6.25 to obtain crude protein. Crude protein is a mixture of true protein and nonprotein nitrogen; it indicates the ability of the forage to meet an animal’s protein needs. It is expressed as a percentage of dry matter and includes both nutritionally available and unavailable nitrogen. Generally, the higher the CP percentage the greater the forage quality.

Insoluble crude protein (ICP) is the amount of unavailable crude protein, including protein which was permanently linked to nonstructural carbohydrates during heating of forage stored at an improper moisture. During fiber analysis, ICP is incorrectly measured as lignin, which can result in errors in data interpretation and ration balancing. Therefore, when heating of the forage is suspected, ICP should be analyzed.

Acid detergent fiber (ADF) is the percentage of highly indigestible plant material in a forage; it is comprised of cellulose, lignin, cutin, silica, pectin, and unavailable protein. It is negatively correlated to digestibility and therefore can be used to calculate dry matter digestibility, digestible energy, and total digestible nutrients. A low ADF value indicates greater digestibility.

Digested dry matter (DDM) is an estimate of the percentage of the forage that is digestible and used as an estimate of energy content. It is determined from the ADF concentration.

Total digestible nutrients (TDN) is the sum total of all digestible organic nutrients (protein and energy) of a forage that are available to the animal, usually expressed as a percentage of DM.

Neutral detergent fiber (NDF) is the percentage of cell wall material in a forage. Partially available to animals, it is comprised of cellulose, hemicellulose, lignin, cutin, and unavailable protein. It is considered an indication of plant maturity and therefore related to DMI. A low NDF indicates greater forage intake by livestock.

Dry matter intake (DMI) is an estimate of the amount of dry forage an animal will eat with only forage being fed. It is expressed in terms of forage dry weight and is calculated by using the neutral detergent fiber concentration.

Relative feed value (RFV) is a way of assigning to a forage a single numeric value which reflects the sum total of several forage quality attributes. The RFV of a forage is calculated as follows: DDM multiplied by DMI gives the forage’s digestible dry matter intake (DDMI); DDMI is then divided by a constant of 1.29; the result is the RFV. The reference forage has a RFV of 100. A high RFV (above 100) indicates a higher quality forage. Relative feed values can also be used to assign quality standards used in forage marketing. Refer to Table 2 for further information on using relative feed values.
### Table 2. Legume, Grass, and Legume-grass Mixture Quality Standards.*

<table>
<thead>
<tr>
<th>Quality standard</th>
<th>Analysis</th>
<th>DDM</th>
<th>DMI</th>
<th>RFV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CP</td>
<td>ADF</td>
<td>NDF</td>
<td>% of DM</td>
</tr>
<tr>
<td>Prime</td>
<td>&gt;19</td>
<td>&lt;31</td>
<td>&lt;40</td>
<td>&gt;65</td>
</tr>
<tr>
<td>1</td>
<td>17-19</td>
<td>31-35</td>
<td>40-46</td>
<td>62-65</td>
</tr>
<tr>
<td>2</td>
<td>14-16</td>
<td>36-40</td>
<td>47-53</td>
<td>58-61</td>
</tr>
<tr>
<td>3</td>
<td>11-13</td>
<td>41-42</td>
<td>54-60</td>
<td>56-57</td>
</tr>
<tr>
<td>4</td>
<td>8-10</td>
<td>43-45</td>
<td>61-65</td>
<td>53-55</td>
</tr>
<tr>
<td>5</td>
<td>&lt;8</td>
<td>&gt;45</td>
<td>&gt;65</td>
<td>&lt;53</td>
</tr>
</tbody>
</table>


Analysis associated with each standard; CP = crude protein, ADF = acid detergent fiber, NDF = neutral detergent fiber and DM = dry matter. CP is not used in calculation of RFV.

Dry matter digestibility (DDM, %) = 88.9 - 0.779 ADF (% of DM).

Dry matter intake (DMI, % of body weight) = 120/x forage NDF (% of DM); BW = body weight.

Relative Feed Value (RFV) calculated from (DDM x DMI)/1.29. Reference hay of 100 RFV contains 41% ADF and 53% NDF.

*From: Minnesota Forage UPDATE Volume XII No. 4, Late Summer 1987.

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The analysis of forages for mineral content is not routinely performed. However, mineral analysis may need to be considered for livestock on a high plane of nutrition (e.g., a lactating dairy cow). In addition, the mineral data also serves as a guide to the effectiveness of your soil fertility program. Although vitamins are required by livestock in very small amounts, their availability in forages is quite variable. Forage analysis for vitamins is rarely performed unless livestock health problems are suspected. Routine additions of vitamins and minerals to rations are recommended to meet nutritional requirements.

**Sampling**

**Obtaining a Representative Sample**

As with soil testing, a representative sample is needed for a meaningful analysis. One forage sample should be sent to the laboratory for each lot of forage. The term lot refers to a specific quantity of similar forage. Lot size may vary from a bale to a barn full of hay, or a wagon load to a silo full of silage. A lot of forage is a crop harvested from a particular field, at a specific cutting, within a two-day period of time. The important consideration in determining the lot is uniformity. Factors that affect forage quality (plant maturity, species and variety, leafiness, harvest and storage conditions, and presence of pests) must be considered when dividing the crop into lots. The following example illustrates the importance of dividing forages into lots for testing and feeding purposes.

To insure a balanced ration for his herd, a dairyman wants to analyze the alfalfa-grass hay he has on hand. His first cutting yielded 600 bales. It was not harvested until the end of May, two weeks late because of competition with corn planting. While the bales were still in the field it rained. The second cutting was made 35 days later and yielded 400 bales which reached the barn without getting wet.

The summary of the two harvests, shown in Table 3, indicates obvious quality differences. Therefore, the dairyman labels the 600-bale first cutting “Lot 1” and the 400-bale second cutting “Lot 2” and has them analyzed separately. Based on the results, he will formulate and feed a balanced ration using Lot 1, then rebalance the ration when ready to feed Lot 2.
Table 3. Differences in Hay of Two Cuttings from the Same Field.

<table>
<thead>
<tr>
<th>First cutting (600-bale)</th>
<th>Second cutting (400-bale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa and grass</td>
<td>Mostly alfalfa</td>
</tr>
<tr>
<td>Many leaves lost due to late harvest</td>
<td>Few leaves lost due to timely harvest</td>
</tr>
<tr>
<td>Rained on before storage</td>
<td>Stored dry</td>
</tr>
</tbody>
</table>

Sampling Procedures

If forage testing is to be of value, the samples must be taken at the right time and proper methods used to ensure accurate representation of the lot. The proper time to take forage samples is as near as possible to the planned time of sale or feeding. An allowance of one week for NIRS and three weeks for traditional chemical analyses should be considered. Proper sampling methods for different types of forages are discussed in the following paragraphs.

Conventional square bales. A bale probe should be used to collect samples. The probe should be approximately 12 to 18 inches long, hollow and at least 3/8-inch in diameter. Most probes are designed to attach to an electric drill or brace. Many Purdue Extension offices in Indiana have a bale probe that may be obtained for short-term usage by residents. Known sources of probes include:

1. A cut-off metal golf club shaft. The handle end of the shaft is also cut off, a plastic bag attached to the end of the handle with a rubber band, and the user drives the golf club shaft into the end of a bale by hand.

2. Penn State forage sampler is an 18-inch probe with 3/4-inch internal diameter available in hand brace or electric drill modes. Available from Nasco Farm and Ranch Catalog, 901 Janesville Avenue, Ft. Atkinson, WI 53558, Phone 1-800-558-9595.

3. Northwest ag forage probe is a 12-inch probe with 1/2-inch internal diameter, equipped with sample collection box and electric drill mode. Available from Northwest Ag, P.O. Box 238, Culver, OR 97734, Phone (503) 546-3335.

4. Oakfield hay sampler is a 1/2-inch metal probe. Available from Oakfield Apparatus, Inc., P.O. Box 65, Oakfield, WI 53065, (414) 583-4114.

5. Utah State hay sampler is a 1/2-inch electric drill, 15-inch steel barrel with a 1/2-inch internal cutting diameter. Contains a built-in sample collection box. Information available from Jody Gale, County Agent, Utah State University, Logan, UT 84322-4820, Phone (801) 864-4377.

6. Hay Chec is a 16-inch machine steel probe, 7/16-inch inside diameter cutting edge. It has a large body with handles for hand use. The probe fits at one end with a threaded receptacle at the other end to receive sample jars. Available from Hodge Products, Inc., P.O. Box 1326, El Cajon, CA 92022-1326, Phone 1-800-854-3565.

A minimum of 20 average-looking bales that represent the lot should be selected for sampling. Steps in obtaining samples from these representative bales are as follows:

1. Take one core drilling from an end of each bale. Insert the probe near the center of the bale's end at a right angle to the surface.

2. Place drillings in a clean plastic bucket.

3. Thoroughly mix drillings.

4. Put about one quart of the mixed drillings in a plastic bag for laboratory analysis.

5. Repeat procedure for each lot, making sure not to mix drillings of different lots.

If a bale probe is not available, reach inside each sample bale and carefully remove a handful of forage. Cut each sample into 2-inch sections with a pair of shears. Mix all samples from a lot and again remove about one quart for analysis.

Large round bales and stacks. Ten sampling bales or compressed stacks from each lot should be selected. The bale probe is used to make drillings from two different locations from each selected bale or stack. Drillings should be made at the top of each stack, while bales should be probed from the sides (not the ends). Mix the drillings from each lot and remove about one quart for analysis. If a bale probe
is not used, sample these large packages by hand as described for conventional square bales, with the exception that two or three handfuls should be removed rather than a single handful.

**Loose hay.** Samples should be taken from at least twelve random locations in the mow or on the stack. To make bale probe drillings, stand on the stack and insert the probe vertically where the hay is compressed between your feet. If a bale probe is not used, obtain samples by hand using the procedure suggested for large package hay. In either situation, about one quart of the total sampling will be needed for laboratory analysis.

**Silage.** Sampling silage presents different problems as compared to sampling hay. Differences in storage structures, feeding sequence, and the presence of silo gases at various stages during the fermentation process must be considered.

A vertical silo will usually contain more than one lot of forage; therefore, sampling a lot before feeding begins is very difficult. While bunker, trench, and plastic-covered piles of silage are somewhat easier to sample, they are often more variable in nutrient composition. Sampling a lot when filling the silo would be a way of getting representative samples for analysis. This sampling method, however, gives an indication of feeding value when the forage entered the silo, but may not provide an accurate assessment of its nutritional and dry matter composition after fermentation. The following is the suggested sampling procedure for silage.

Collect about 2 gallons of silage in a clean plastic container by taking handfuls at random from 20 different locations on the exposed face or surface (avoid rotted silage on top) or by passing the container beneath the chute several times (once a minute), collecting one or two quarts at each pass while the silage is unloading. Mix subsamples thoroughly and place about one quart in a plastic bag for analysis.

To identify different forage lots, several bales of straw, shavings, or shredded paper can be fed through the blower when the last of each lot is ensiled. The presence of silo gases should be of utmost concern when obtaining silage samples during the fermentation phase.

**Preparation of Samples**

The plastic bag containing the forage sample to be analyzed should be tied or taped shut and labeled with your name, address, and the lot number. In the case of silage, double wrap the sample for further protection. Most testing laboratories will provide a description sheet for sample identification. On this sheet include your name, address, forage description and lot identification, and tests desired.

If mailing the sample, be sure the plastic bag is airtight. Place this bag inside a rigid cardboard box, along with the description sheet. The rigid outer container will prevent the bag from being punctured during shipment. With silage samples, freeze the sample prior to mailing and mail early in the week to avoid weekend delays.

**Testing Laboratories**

Several feedstuffs testing laboratories perform forage analyses. Contact any one of these laboratories for a complete and current description of services provided, components tested, testing fees, and mailing instructions. If you know of other reputable laboratories that provide reliable forage testing, do not hesitate to utilize their services.

**Wisconsin DHI Cooperative**
Box 7
Bonduel WI 54107-0007
715/758-2178
(work with DHIA supervisor)

**Litchfield Analytical Services**
535 Marshall St., PO Box 457
Litchfield, MI 49252
517/542-2915

**A & L Great Lakes Laboratories, Inc.**
3505 Conestoga Dr.
Fort Wayne, IN 46808
219/483-4759

**Brookside Farms Lab Assn., Inc.**
308 S. Main St.
New Knoxville, OH 45871
419/753-2448

**Central Laboratory**
Indiana Farm Bureau Co-op Assn., Inc.,
2435 Kentucky Ave.
Indianapolis, IN 46241
317/243-1502
(work through local member association)

**Chemical Service Laboratory, Inc.**
3600 Chamberlain Lane, Suite 360
Louisville, KY 40241
502/429-5238
Application of Forage Testing Results

Forage testing helps producers, nutritionists, veterinarians, and researchers make knowledge-based decisions. The following sections describe four important uses of forage testing results.

On-farm Improvement of Forage Production and Quality

One of the most common factors influencing forage quality is plant maturity. Forage testing allows producers to see how nutrient composition changes as the crop matures. This is accomplished by comparing the test results of a forage cut at a very mature stage to a similar forage harvested on a more timely basis. Forage testing could also help the producer better assess the need to renovate existing fields or establish new forage stands.

The application of drying agents and preservatives to enhance forage quality by reducing curing time can be evaluated by comparing test results of forage that was or was not treated. This evaluation can then be applied to management decisions in future years. Testing forages prior to storage is helpful in determining specific precautions needed to maintain quality. Nutrient losses during storage can be determined by testing forages prior to storage and again before being used. This procedure allows the producer to evaluate storage facilities and techniques.

Forage Marketing

Forage testing makes marketing on the basis of feeding value possible. This practice aids the seller in pricing hay and provides valuable information to the buyer about how to use a forage most effectively in a livestock feeding program.

The National Forage Testing Association is working to bring the various hay testing and grading systems currently used into one common system. It has developed a national certification program for forage testing laboratories which utilizes a standard set of important forage analyses (DM, CP, and ADF) and includes visual standards. The adoption of a national system will make interstate transfer of forages more common since descriptive terms will be uniform.

Forage testing in the marketplace has been limited because of the lack of a rapid analytical procedure. The recent development of NIRS has been shown to be a solution to this limitation. The NIRS procedure has been tested at hay markets and has provided accurate and rapid nutritive analysis without disrupting sales.

Forage testing is not intended to be a mandatory requirement for forage marketing. Instead, it should be considered a tool for negotiating the price of hay or silage. The costs of producing high quality forage is greater than those associated with forage of low quality; therefore, high quality forages should be of greater value to livestock producers if forages represent a large part of the ration. If improved forage quality results in increased animal performance and increased animal performance provides for greater profits, the costs associated with forage analysis are easily offset by the benefits gained.

Ration Formulation

In the past, producers have formulated rations from "book values." While book values do predict average nutrient composition, they do not take into account many factors that affect nutrient availability and intake. Only forage testing can precisely evaluate the composition.

Using forage testing to formulate livestock rations takes into account two basic goals—development of nutritionally balanced rations and development of least-cost rations. Forage testing provides information that helps determine the best use of a forage and what supplements, if any, are needed to achieve desired levels of animal performance. It is important to keep in mind that different livestock classes have different nutritional requirements which must be met by the ration. Livestock classes are generally separated by intended purposes of production, production levels, body weight, and frame size.

The Cooperative Extension Service can assist you in a number of ways, using your forage analysis to balance rations for your livestock.

1. You can obtain a copy of the nutrient requirements for beef cattle, dairy cattle, horses, and sheep at your local Extension office and formulate your own rations.

2. You and your county agent can work together, using the Extension office's computer, to formulate rations specific to your needs and available forages. Several computer programs are available for this purpose. Currently, ration analyzer and ration formulation programs are available for dairy, beef, swine, sheep, and horses.

3. Assist you in getting in contact with individuals trained in animal nutrition and ration formulation who can guide you in making optimum use of your feed test results.

In order for forage testing to be successful in ration formulation, samples must be representative of separate lots and analyzed by a reputable firm. Nutrient requirements and livestock data must be known, accurate, and complete.
Research

Traditionally, increased yields and improved disease resistance have been stressed in forage breeding programs. Forage quality has been a concern in breeding programs recently, but progress in improving quality through plant breeding has been slow. Forage testing can help identify germplasms and varieties that are superior in quality to current varieties marketed. Forage testing is also used to monitor compositional changes of plants as a result of management practices. Nutrient composition is altered by fertilizer applications, pest control practices, harvest schedules, and storage systems. New technology and management practices can first be evaluated in research studies by using forage testing. This allows scientists the opportunity to investigate the cause and effect relationships that new management advances have had on forage quality, prior to recommendation for on-farm use.

For assistance in interpreting or using forage testing results to their maximum benefit, contact your Purdue University Cooperative Extension Service agent.