Hay Quality, Sampling, and Testing

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INTRODUCTION TO HAY TESTING

Hay is one method of forage preservation for animal feed, and hay can be kept for long periods of time with little loss of nutrients if stored properly. Alfalfa is New Mexico's number one cash crop, and value of hay sales exceeds $200 million annually. Much of New Mexico's hay is marketed to the dairy industry; however, significant quantities are sold to the horse and other livestock markets as well.

Knowing the actual nutritive value of a hay is very important for both seller and buyer. High-quality hay brings a good price for the grower and allows the dairy to feed less grain to cows. Dairies want a hay with a high relative feed value (RFV) and a high digestibility that contribute to maximum milk production. Much of the hay for horses is sold based on appearance, and horse owners prefer soft, leafy, and green alfalfa that is free of blister beetles. Because hay is such a large part of New Mexico's agriculture and economy, accurate hay quality estimates are critical not only for economic stability but for hay grower and dairy and horse industry livelihoods.

Occasionally, questions arise concerning the value of testing alfalfa and other hay and using a forage quality measurement such as RFV as a basis for labeling and marketing. Feed, seed, and fertilizer manufacturers and distributors have wrestled with this problem in the past, and each sector has developed a method of communication between buyer and seller, called the "guaranteed analysis." The analysis gives the buyer an idea of what to expect from the product. Guidelines have been established for label contents, sampling and analysis procedures, and, in some cases, penalties for noncompliance. Hay grading systems must fairly reflect quality for both the seller and the buyer of the product. This is difficult with a forage product whose quality can vary across a field and is inconsistent throughout a bale due to random distribution of leaves and stems.

During the last 10 to 15 years, forage analysis has become a valuable tool for hay marketing mainly because of increased awareness and technology in the beef and dairy cattle industries. Sampling procedures and laboratory certification guidelines have been developed based on a recognized need to standardize hay sampling and analysis and to assist those marketing hay based on the forage analysis. The following information regarding the National Forage Testing Association and their guidelines can be obtained from their Web site at www.foragetesting.org.

In 1984, the American Forage and Grassland Council (AFGC), the National Hay Association (NHA), and forage testing laboratories combined to form the National Forage Testing Association (NFTA) to improve the accuracy of forage testing and build grower and consumer confidence. Workshops offering participants information on the latest research and developments in forage testing have been held in conjunction with the annual Association of Official Analytical Chemists (AOAC) International Midwest meetings. The NFTA certification program is updated each year to include new methods of grading laboratory performance. Since participation in the certification program is voluntary, not all hay testing laboratories are involved. Additionally, not all those participating receive certification.

Presently, laboratories are evaluated and graded six times every year. Reference samples, including four alfalfa samples (one of which contains approximately 20% grass) and one sample each of corn silage and grass, are sent to each laboratory, which analyzes them using standard, accepted techniques. Currently accepted techniques of forage analysis include traditional wet chemistry and near infrared reflectance spectroscopy (NIRS); NIRS is a newer technique that uses light reflectance. Although the initial investment for equipment is high, NIRS is quicker and cheaper in the long run than wet chemistry and gives equivalent results. Some laboratories will use only one technique, while others use both. The same sample is used in both techniques and grading is the same. Grading is done on

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the final cumulative bias total accuracy for all analyses (e.g., percent dry matter, crude protein, acid detergent fiber, and neutral detergent fiber).

When the results from each laboratory are received, they are compared to each other to determine if all laboratories came up with the same analysis within specific limits (bias from the average). Those laboratories within the specified limits are certified. Nationally certified laboratories located in selected states are listed on the www.foragetesting.org Web site. Certified laboratories receive an NFTA-certified stamp for the year they are certified, and increasingly hay dealers, brokers, nutritionists, and dairy producers will only base their negotiations on certified analyses. For information on specific laboratories, check the NFTA Web site or ask for proof of certification. For more information about the National Forage Testing Association, visit the NFTA Web site or contact:

National Forage Testing Association
P.O. Box 451115
Omaha, NE 68145-6115
www.foragetesting.org

SAMPLING GUIDELINES FOR HAY TESTING

Quality analysis is an important alfalfa hay marketing tool for sellers and buyers, and sampling technique is a significant aspect of standardized hay testing. A hay quality analysis is valid only to the extent to which the sample represents the lot of hay. In addition, because the actual amount of sample that will be analyzed in the lab may be as little as 0.5 g, it is imperative that an accurate and representative sample be taken. Hay sampling errors can add more variation to quality results representing the whole lot than laboratory errors. A lot is defined as up to 200 tons of dry matter (approximately 225 tons of hay at 12% moisture) baled from the same field, cutting, and stage of maturity. Any given lot can be packaged in any form or size of bale or stack. Although there can be considerable bale-to-bale variation, proper sampling practices will incorporate this variability to represent the overall quality of the lot.

What to Use for Sampling

The sample for each lot should consist of cores from at least 20 bales and weigh approximately 0.5 lb. Cores are taken using a hollow tube probe with an inside diameter of 3/8 to 5/8 in. that can take a 14- to 24-in. long core. Using a probe with a greater diameter or length or taking more than 20 cores may make the sample too large. In contrast, probes with smaller diameters may tend to push stems out of the way and gather only leafy material, thereby giving a misleading high-quality result. Even if the sample is large it should not be divided because stems and leaves will separate and settle, creating subsamples that do not represent the lot. Send the whole sample to the laboratory. The probe's cutting tip should be kept sharp to make coring easier and prevent the hay from wadding around the outside. Some commercial probes come with a replaceable cutting tip; for others, sharpening is best done using a round file to scallop the inside edge. A listing of hay probe types and company information is available on the NFTA Web site.

How and Where to Sample

Sample rectangular bales of any size by centering the probe in the end of the bale and drilling horizontally into the bale. Round bales are sampled by drilling horizontally into the center of the bale's curved side. If only the bale's sides are exposed or fewer than 20 ends are exposed, as with large bales on a truck, drill on a sharp angle from as close to the end of the bale as possible and in the vertical center. Sample bales at random. There should be no predetermined reason to select a specific bale (location, color, leafiness, etc.). Hay bale "flakes" and grab samples are unacceptable for testing because they do not provide a good, random sample.

To sample bales still in the field, count the number of bales, divide by 20 (= n) and sample every nth bale. For example, a farmer just baled a 120-acre circle of alfalfa. There are 4,800 small square bales in the field weighing about 75 lb each (180 tons). Since 4,800 / 20 = 240, the farmer will probe at least every 240th bale to get exactly 20 cores. If 1-ton bales are made, the farmer will have 180 bales, and in this scenario every 9th bale should be sampled (180 / 20 = 9). If those bales are not randomly distributed throughout the field, the farmer may want to take 25 or 30 cores rather than 20 to get a more random distribution. Remember, though, that taking more cores may make the sample too large. For stacked hay or truckloads, take an equal number of cores from each accessible side. Count the number of bale ends exposed, divide by 20 as before, and sample every nth bale. If the lot contains fewer than 20 small square or large round bales, core all the bales. If there are less than 20 large square bales, core each bale twice, but from opposite ends if possible. If deteriorated hay from the exterior of the bale or stack will not be fed to animals, or if they can be selective in their feeding, it should not be included in the sample. Otherwise, if hay is sold based on quality or if it will be ground before feeding, the deteriorated portion should be included in the sample.

When to Sample

During the three weeks following baling, hay undergoes a "sweat" that results in a decline in quality. This sweat is a result of continued bacterial respiration that consumes plant sugars and produces heat. In time, bacterial activity slows, heat generation ceases, and the hay stabilizes to what is referred to as cured hay. Any hay that will not be fed for more than three weeks should be sampled as close to feeding time as possible. Additionally, hay stored outside should be sampled within two to four weeks of feeding so that continued deterioration does not significantly lower bale quality compared to the sample taken for analysis.

Take samples early in the week, seal them tightly in an airtight polyethylene bag (e.g., zipper-type freezer bags), and immediately mail or deliver them to the laboratory so they will not spend the weekend in shipment. The laboratory report for "As Received" or "As Fed" will more accurately approximate the lot of hay for samples handled in this way. Label each sample with the lot, area where grown (field), forage type (species), cutting, stage of maturity, and special conditions (e.g., rain/sun damage, frosted, drought, etc.). Use a fine point permanent marker for labeling directly on the sample bag. It also may be helpful to include a label inside the bag, written with the fine point permanent marker.

FORAGE QUALITY ANALYSIS: DEFINITIONS

Laboratory evaluation of alfalfa and other hay quality may be performed by chemical analysis or by near infrared reflectance spectroscopy (NIRS). Once the results are obtained from the laboratory, estimation of actual quality or feeding value must be determined. Below are some of the terms used in quality analysis, what they mean, and how they are calculated.

Dry matter (DM) is the percentage of the forage that is not water. If a forage is 55% dry matter, then it has 45% water (100 – 55 = 45). Rations are balanced on a dry matter basis. Most laboratories will report results in two columns: "As Sampled" or "As Received" and "Dry Basis" or "Dry Matter Basis." Only values designated as "Dry Basis" can be compared across parameters. "As Sampled" values can be converted to "Dry Basis" by multiplying by the actual DM percentage.

Crude protein (CP) is a mixture of true protein and non-protein nitrogen, and also includes insoluble crude protein. It is estimated by measuring the total nitrogen in the sample and multiplying this value by 6.25. In general, a high CP level is desirable, but a high CP level is not always indicative of highly nutritious forage. It is usually obtained by harvesting at an early growth stage. Crude protein declines with maturity in most forages. Heat damage can alter protein availability, and CP values give no indication if heat damage has occurred.

Insoluble crude protein (ICP) and **acid detergent insoluble nitrogen (ADIN)** refer to the proportion of CP that is not available to the animal and are an indicator of the amount of heating that has taken place in storage. A low ICP value is desirable, and the ICP:CP ratio should be less than 0.1, indicating that harvest and storage practices were correct. ICP:CP ratios higher than 0.1 can occur when cutting is delayed, hay is baled too wet, or haylage is stored too dry, resulting in excessive heating that can cause significant heat damage.

Adjusted crude protein (ACP), also referred to as degradable protein, is the amount of crude protein available to the animal for digestion. It is adjusted for the amount of bound or insoluble protein: ACP = CP – ICP.

Neutral detergent fiber (NDF) represents the cell wall portion of the forage and includes hemicellulose and the ADF components. The NDF portion is only partially digestible. Neutral detergent fiber is negatively correlated with intake—the higher the percentage NDF, the less of the forage the animal will eat. Thus, low NDF is desirable. Neutral detergent fiber increases as forages mature.

Dry matter intake (DMI) is based on NDF concentration and is an estimate of the amount of forage an animal will consume. Feeding studies have shown that as percent NDF increases in forages, animals tend to consume less. Therefore, NDF can be used to estimate DMI. Use the following formula to estimate DMI:
DMI (% of body weight) = 120 / NDF (% of DM).

Neutral detergent fiber digestibility (NDFD) is a relatively new term that expresses digestible neutral detergent fiber (dNDF) as a percent of actual NDF. It is an indicator of how much of the total cell wall is digestible. Digestibility of NDF can be determined by in vivo, in vitro, and in situ techniques in addition to NIRS analysis.

Acid detergent fiber (ADF) represents the portion of the forage remaining after a weak acid digestion and contains cellulose, lignin, silica, and insoluble nitrogen compounds. In general, as forage plants mature, ADF increases and digestibility of forage decreases. While it has been commonly used to predict digestibility, ADF has not been shown consistently to be highly correlated with actual digestibility. Low ADF is desirable. ADF is commonly used to calculate DDM and TDN.

Digestible dry matter (DDM) is a calculated value used to estimate the percentage of the forage that is digestible as determined from ADF. Digestible dry matter can be used to estimate the energy value of the forage, but other estimates are perhaps more suited for energy. The lower the ADF, the higher the DDM will be. Digestible dry matter is used in the calculation of RFV. The following formula is used to calculate DDM: DDM (%) = 88.9 – [0.779 * ADF (% of DM)].

Total digestible nutrients (TDN) is an estimate of the total amount of nutrients in a forage that is digestible by the animal. Historically, it has been calculated from ADF similar to DDM; however, newer calculations summing CP, non-fiber carbohydrates, dNDF, and fat may be more accurate (e.g., TDN = NFC * 0.98 + CP * 0.93 + FA * 0.97 * 2.25 + 0.75 [NDF * in vitro NDFD / 100] – 7). (FA = fatty acids, NFC = non-fiber carbohydrates)

Net energy for lactation (NEL) is an estimate of the energy of a particular forage that is used for maintenance of the animal in addition to milk production during lactation. It is most commonly used for predicting how a forage will meet the energy needs of dairy cows. This system is based on the utilization of the forage by the animal at specific levels of energy requirements. Net energy for maintenance (NEM) and for gain (NEG) are two other components of the net energy system, and represent estimates of energy required for basic metabolic processes and body gain (i.e., weight) of the animal, respectively.

Relative feed value (RFV) is an index that combines ADF (DDM) and NDF (DMI) nutritional factors to arrive at one number to measure and compare forage quality. It has been used to allocate forages with varying digestibility and intake to different livestock classes. In addition, it is still used extensively for marketing hay and price determination. This index is becoming outdated and a newer index (RFQ, see below) is replacing RFV as the industry standard. The following formula is used to calculate RFV: RFV = DDM * DMI / 1.29.

Relative forage quality (RFQ) is a better index and estimate of actual forage quality than RFV, and better predicts how an animal will perform on a particular forage. It is calculated from TDN and intake based on in vitro estimates of digestible fiber instead of ADF, which RFV uses. For convenience, index value ranges have been kept similar to those of RFV. It is considered a more fair method of setting hay prices for both buyer and seller. When both values are given, RFQ should be used. The analysis in Table 1 includes a 48-hr in vitro analysis of the NDF fraction, which allows RFQ to be calculated, next to RFV. Knowing RFQ helps explain unexpected milk response differences in dairy cows from apparently similar testing hays (based on RFV). The following formula is used to calculate RFQ: RFQ = (DMI, % of body weight) * (TDN, % of DM) / 1.23.

Table 1. Example of a Quality Analysis Report from a Legume Hay Submitted to a Commercial Laboratory

Legume	As Sampled	Dry Matter	Unit
Moisture	11.8		%
Dry Matter	88.2		%
Crude Protein	17.8	20.1	% DM
Soluble Protein	7.8	8.9	% DM
		44.0	% CP
Degradable Protein (calc.)	12.8	14.5	% DM
		72.0	% CP
TDN	62.6	70.9	% DM
Net Energy Lactation	0.65	0.74	Mcal/lb
Net Energy Maintenance	0.67	0.75	Mcal/lb
Net Energy Gain	0.42	0.48	Mcal/lb
Acid Detergent Fiber	22.9	25.9	% DM
Neutral Detergent Fiber	26.9	30.5	% DM
Ndf 48 hr digestibility		48.4	% NDF
Ash	9.7	11.0	% DM
NFC	32.3	36.6	% DM
Calcium	1.61	1.82	% DM
Phosphorous	0.20	0.23	% DM
Magnesium	0.29	0.33	% DM
Potassium	2.40	2.72	% DM
Sodium	0.144	0.163	% DM
Iron	183	208	PPM
Manganese	37	42	PPM
Zinc	23	26	PPM
Copper	7	8	PPM
Relative Feed Value (RFV)	210		
Relative Feed Quality (RFQ)	213		

DM = dry matter, CP = crude protein, Mcal = megacalories, NDF = neutral detergent fiber, NFC = non-fiber carbohydrates, TDN = total digestible nutrients

HAY GRADING AND QUALITY STANDARDS

Hay now is shipped not only across state lines but to different countries, making a standardized product evaluation essential. While current standards still do not require specific laboratory or digestibility nutrient analysis testing, alfalfa hay standards do provide a slightly more specific distinction among classes of hay. This ensures

Table 2. Quality Standards for Legume, Grass, or Mixed Hay

Quality Standard	Legume Stage	CP	ADF	NDF	DMI	RFV/RFQ
Prime	Bud, Pre-bloom	> 19	< 31	< 40	> 3.0	> 151
1	Early flower	17–19	31–35	40–46	3.0–2.6	151–125
2	Mid-bloom	14–16	36–40	47–53	2.5–2.3	124–103
3	Full-bloom	11–13	41–42	54–60	2.2–2.0	102–87
4	Full-bloom	8–10	43–45	61–65	1.9–1.8	86–75
5	Mature or damaged	< 8	> 45	> 65	< 1.8	< 75

Source: Hay Market Task Force, American Forage and Grassland Council.

CP = crude protein, ADF = acid detergent fiber, NDF = neutral detergent fiber, DMI = dry matter intake, RFV = relative feed value, RFQ = relative forage quality

Table 3. Alfalfa Hay Quality Guidelines Commonly Used for Marketing in the Western U.S.

Hay Quality Category*	CP	ADF	NDF	TDN	RFV
Supreme	> 22	< 27	< 34	> 62	> 185
Premium	20–22	27–29	34–36	61–62	170–185
Good	18–20	29–32	36–40	58–60	150–170
Fair	16–18	32–35	40–4	56–58	130–150
Low/Utility	< 16	> 35	> 44	< 56	< 130

* All quality parameters are based on 100% DM

Abbreviations: CP = crude protein, ADF = acid detergent fiber, NDF = neutral detergent fiber, TDN = total digestible nutrients, RFV = relative feed value

fairer pricing because it also provides a better estimate than appearance of feeding value prior to purchase.

The quality parameters described in the previous section can be examined after laboratory analysis and results compared to the ranges of standards and marketing categories in Tables 2 and 3 in order to determine rank and value of a particular hay. While RFQ is considered a better index to use, RFV is still very popular and widely used throughout the western U.S. for determining quality and price of hays. However, RFV is calculated based only on the amount of ADF and NDF, and doesn't take into account the digestibility of the fiber fraction. On the other hand, RFQ takes NDFD into account and helps explain variation in milk production responses to similar testing hays based on RFV. In addition, crude protein is another important factor in ranking quality of hay. Slight changes in any of the quality values (especially RFV and CP) can have a significant effect on negotiated hay price, whether justified or not. Standards for alfalfa hay are higher than those for grasses or legume/grass blends, and the expected high quality of alfalfa is evidenced by the common desire among dairies in the West to purchase "supreme" hay (Table 3).

VISUAL ESTIMATES OF QUALITY

Early hay standards established grades on visual estimates only, but these estimates of quality were subjective and difficult to substantiate. Still, while it is not recommended to assess hay quality on appearance alone, certainly visual observations of the hay are important. An initial visual estimate of hay quality can alert you to hay that might or might not be worth buying. It is difficult to estimate the actual nutritive value of hay based on looks, and visual criteria are not necessarily related to animal performance. Bright green, vibrant looking hay may not always test high, and hay with a poor appearance may be of good quality but give an impression of low nutrition. Buyers and sellers should use both laboratory results and visual appraisal to set a fair price. Several factors should be considered when inspecting a bale or load of hay, including maturity, leafiness, color, proportion and coarseness of stems, foreign material (including weeds), odor, mold, and dust. Leaves are the most digestible part of the plant and contain the most protein, so they should be retained as much as possible. Also, green color is an indicator of high vitamin A content and implies proper curing.

Visual inspection is complicated by the fact that any one bale is not a uniform product. Distribution of leaves and stems is not uniform throughout the bale. In addition, large variability can exist from one part of the field where the hay was harvested to another, leading to bale-to-bale variation. This further supports the need for good representative samples for laboratory analysis to be taken not only from individual bales but from the whole lot as well.

The laboratory quality parameters in Table 3 should be used with and coincide with the physical descriptions within each category listed below.

Supreme: Very early maturity, pre-bloom, very soft, fine-stemmed, extra leafy—factors contributing to a very high nutritive content. Hay is excellent in color, free of damage, mold, dust, or foreign material. For legumes, this will occur at bud to first flower or just before blooming.

Premium: Early maturity, pre-bloom, fine-stemmed, extra leafy—factors contributing to a high nutritive content. Hay is green and free of damage, mold, dust, or foreign material (< 5%). Also occurs from bud to first bloom in legumes.

Good: Early to average maturity, that is, early- to mid-bloom (first flower to 50% of plants in bloom). Leafy, fine- to medium-stemmed, free of damage, mold, and dust, slight discoloration.

Fair: Late maturity, mid- to late-bloom (> 50% of plants in bloom). Moderate or low leaf content and generally coarse-stemmed. Hay may show slight damage.

Low/Utility: Hay in very late maturity with mature seedpods. Very coarse-stemmed. Could include hay discounted due to excessive damage and heavy weed content or mold.

While laboratory analyses and visual inspections are helpful in determining the feed value of hay, the most accurate test of quality is animal performance. High-quality hay will be readily consumed. Animal performance is determined by intake, digestibility, and nutrient content, and is also impacted by toxic compounds within the hay product. Some hay or hay mixtures are just naturally preferred by animals. Softer, leafier hay is more palatable than hay with more stems (less digestible) or hay that has lost leaves due to pest problems or leaf shatter at baling. The hay must also be free of harmful components that might limit animal intake. This includes not only toxic compounds within the hay or weeds that were also harvested but also dust or mold that may have accumulated within the hay product during baling or storing or at feeding.

Weeds can lead to considerable reductions in price and should be eliminated as much as possible regardless of their quality. Buyers, whether purchasing for dairy cows or horses, desire hay that is free of weeds, and growers should recognize a price incentive to maintain a weed-free crop. Some states such as Colorado and New Mexico have a weed-free certification program that has added another set of criteria to certain certified hay sold in and out of state. Few states have implemented a weed-free certification program due to additional costs for color-coded twine used on certified bales and the need for multiple inspections in the field in addition to an inspection of the final product. With weed-free certification, however, another sales class of alfalfa hay has emerged for marketing beyond the quality standards of supreme, premium, good, fair, and low/utility. For the weed-free program, hay fields are inspected for the presence of certain weeds shortly before harvest. The harvested hay is certified rather than the field, so each cutting must be certified. Certified weed-free hay must be labeled as such. Although not required, it usually can be identified by color-coded twine. This is the best form of proof, as the twine is only available through the certification program. There are no other classes within the weed-free certification program, and a hay is either certified weed-free or not certified.

Aside from feeding the product, forage quality analysis is the best estimate of animal performance and, consequently, the best basis for hay pricing. Only a properly collected and analyzed sample is of value in this regard. Bear in mind that ultimate forage nutritive value is determined by the animal to which the hay is to be fed. Some species of livestock will perform best on lower quality hay than what is necessary to sustain a highly productive dairy cow. Be sure to balance your ration for the animals to be fed. Consult your County Extension Agent for questions regarding formulating rations for your livestock.

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