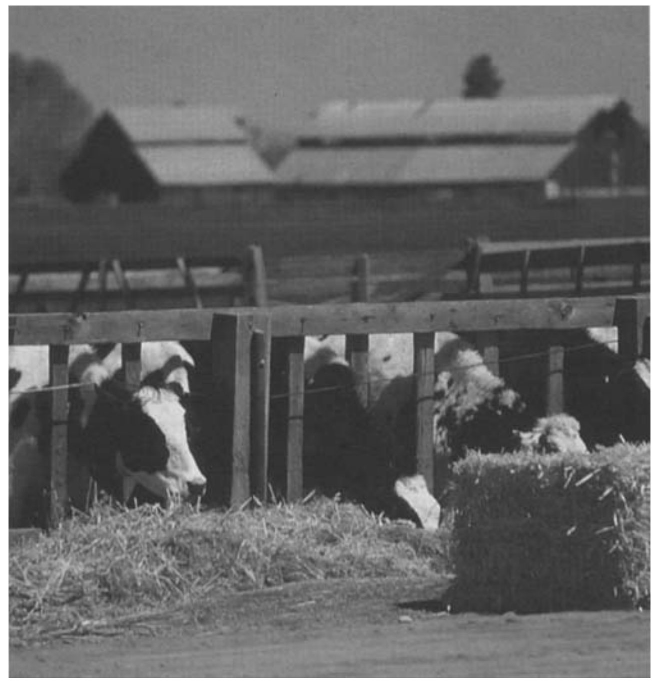
CHAPTER THIRTEEN

QUALITY AND QUALITY TESTING

Steve B. Orloff and Vern L. Marble



Alfalfa hay grown in the Intermountain Region has a well-deserved reputation for high quality. It is marketed locally and throughout much of California, in other states, and internationally. Producers recognize the importance of growing high-quality hay. Quality has a profound effect on animal performance and milk production and, consequently, the value and price of alfalfa hay.

WHAT IS QUALITY?

Forage quality is a relative term. What is considered high-quality alfalfa depends on one's perspective (whether one is the buyer or seller), on current market conditions, and, most importantly, on the intended use for the alfalfa. From a nutrition perspective, forage quality relates to the feeding value of the hay, or the ability to convert hay into milk, meat, and fat. Forage quality is a function of both forage intake and digestibility. As forage quality increases, feed intake and digestibility increase.

Like all living organisms, alfalfa plants are composed of cells (Figure 13.1). Alfalfa cells consist of the soluble and highly digestible contents of the cell (protein, sugars, fats, starch, and pectins) and the less digestible, structural parts of the cell wall (cellulose, hemicellulose, and lignin). Cell wall content is the most important factor affecting forage utilization and, thus, forage quality. Fiber analyses can indicate the cell wall content of alfalfa hay (fiber analyses are discussed later in this chapter).

Low-quality alfalfa has a high proportion of cell wall material, and the cell walls are composed of a relatively large amount of indigestible compounds, such as lignin. Lignification of the cell wall, which occurs as alfalfa plants mature, is the primary factor limiting forage digestibility. High-quality alfalfa, in contrast to low-quality alfalfa, has less cell wall material, and the cell walls are thinner and contain less cellulose and lignin. Not only is high-quality alfalfa more nutritious, but it is also more palatable and digestible. Therefore, animals consume it in larger quantities.

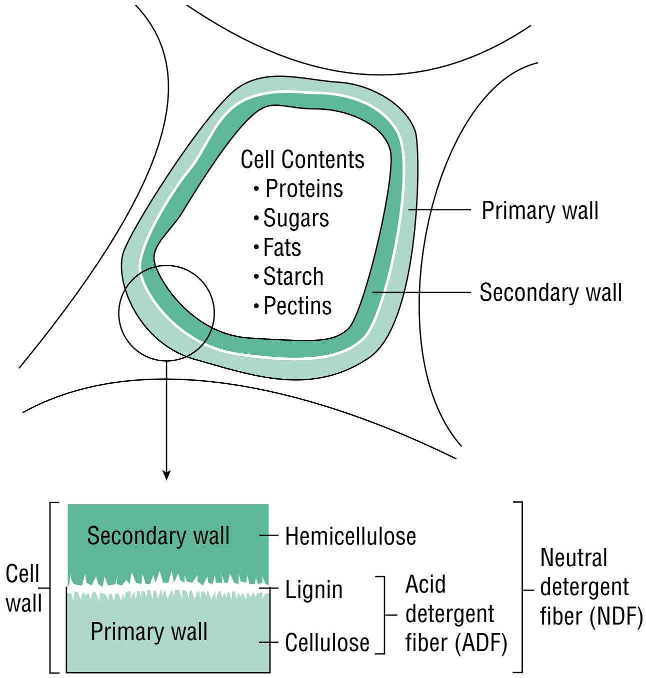


Figure 13.1. Diagram of a plant cell showing cell wall structure and cell components. (Courtesy Pioneer Hi-Bred International, Inc.)

QUALITY REQUIREMENTS

Forage quality needs depend on livestock class—that is, whether the consumers are high- or low-producing dairy cows, or beef cattle, or ruminant versus non-ruminant animals. High-producing dairy cows require highly digestible, high-energy, high-protein forage. Milk output from dairy cows fed low-quality alfalfa hay will never equal milk output from cows fed high-quality hay. Compared to high-quality alfalfa, low-quality alfalfa remains in the ruminant digestive tract longer; this results in decreased intake and animal productivity. Supplements can only partially compensate for low-quality hay in the diet. Compared to high-producing dairy cows, low-producing cows, nonlactating cows (dry cows), and beef cattle have lower nutrition requirements; they do not require top-quality alfalfa. Similarly, horses (especially inactive "hobby horses") have lower energy requirements than do lactating dairy cows. In fact, horses can become colicky when fed alfalfa of too high a quality. Unlike ruminants, horses can respond to eating low-quality hay by increasing their consumption of it and passing it through their digestive system more rapidly; this response compensates for the low quality. The primary criterion when judging alfalfa hay for horses is not its energy value but its condition. Hay for horses should be free of dust, mold, and weeds.

FACTORS AFFECTING QUALITY

Numerous factors, both controllable management factors and uncontrollable environmental factors, influence alfalfa hay quality. Unfortunately, alfalfa quality and yield are usually inversely related. In other words, factors that result in high yields usually result in decreased forage quality; conversely, factors that decrease yield increase forage quality.

Harvest management and variety selection

Stage of maturity at the time of cutting is the most important controllable factor (see chapter 11). Quality declines with advancing alfalfa maturity. However, yields increase with advancing maturity, so harvest management is a compromise between maximum yields and maximum quality. Alfalfa variety selection influences forage quality (chapter 3), as do hay-making practices (chapter 12). Raking or baling when the hay is too dry results in excessive leaf shatter and reduced quality. Heating and mold growth occurs in hay that is baled too wet. Although quality differences among alfalfa varieties are not great compared with differences in other characteristics, most alfalfa seed companies are making a major effort to improve forage quality through breeding. When available, varieties that are higher in quality may increase management options, but they will not replace the need for sound cultural practices.

Seasonal effects

Seasonal variations in light, moisture, temperature, and photoperiod (day length) all affect forage quality. Alfalfa harvested in the spring, or late summer or fall, has a higher leaf and protein content than summer-produced alfalfa of the same maturity. Therefore, the quality of the last hay cutting (third or fourth) is typically the highest of the year. The first cutting produces higher quality than midsummer hay cutting(s).

Soil moisture

Either too much or too little water can impact yield and quality; however, the relationship is not clear-cut. The usual effect of drought stress is a stunted plant that, compared to unstressed plants, is leafier, has finer stems, and less fiber, and is more digestible. However, the effect of drought stress on forage quality may depend on the severity and timing of the stress. Severe stress may result in leaf loss and a reduction in quality. At any rate, the yield reduction incurred from moisture stress (see chapter 4) is too great a price to pay for high-quality hay. Soil type also affects forage quality, but it is difficult to distinguish the effects of soil type from its indirect effect on water-holding capacity, soil aeration, and nutrient availability. In general, alfalfa produced on very fine-textured clay soils or salty soils is shorter, finer stemmed, and leafier than alfalfa grown on loam or sandy soils.

Pests

Insects, diseases, and nematodes can either increase or decrease forage quality, depending on the type of damage they inflict. Pest pressures that delay alfalfa development typically result in higher forage quality, but they reduce yields. Some diseases and nematodes may retard plant growth and yield, resulting in improved quality. On the other hand, some pests cause a reduction in the leaf-to-stem ratio, an increase in fiber concentration, or a reduction in protein concentration. All these changes lower feeding value. For example, leaf and quality loss is often associated with insect feeding and disease pressure. The presence of weeds in alfalfa hay almost always reduces forage quality because most weeds are less palatable and nutritious than alfalfa.

Rainfall

Like environmental factors, weather conditions after alfalfa is cut influence quality. Rain is a continual threat in the Intermountain Region. Rainfall can decrease forage quality considerably—it can shatter and destroy leaves, leach soluble nutrients, and prolong respiration. The force of raindrops hitting drying alfalfa disconnects leaves from the stem. The wetting and drying process increases the potential for leaf shatter. Rain-damaged alfalfa can be brittle after drying, so it is more susceptible to loss during raking or baling. Extra operations may also be necessary to dry the rewetted alfalfa, and these may increase mechanical losses and reduce forage quality.

Leaching of soluble nutrients is the primary cause of quality loss. Rain leaches the more soluble, highly digestible nutrients from alfalfa. It leaches some of the soluble protein and reduces the digestibility of the remaining protein. As a result, rain damage decreases digestibility and increases fiber concentration. Rainfall can cause additional losses by prolonging respiration. After it is cut, alfalfa continues to respire until its moisture content drops to less than 40 percent. Rain rewets the forage and allows respiration to continue.

The effect of rain on alfalfa quality depends on the amount, intensity, and duration of the rain as well as the moisture content of the alfalfa at the time of rainfall. Leaching losses increase as the amount and duration of rainfall increase. An intense rain for a short time has less effect on forage quality than the same amount of rain over a longer duration. Both leaching and leaf loss are greater with drier alfalfa than with that which is freshly cut. Rain early in the drying process causes little loss: The cuticle, or outer coating on the plant surface, is largely intact soon after cutting and is believed to shed water better at that point than when the forage has dried.

Because of these variables, it is difficult to predict the quality of rain-damaged alfalfa hay. Just because rain falls on cut alfalfa does not mean that it is unsuitable for the dairy market. Rain often has a greater effect on the visual appearance of hay than on its nutritional value. Chemically analyze rain-damaged hay to determine its suitability for dairy cows; do not rely on its visual appearance.

Sampling . . . is the primary factor affecting the accuracy of quality analysis.

HAY EVALUATION

The ultimate test of hay quality is animal performance. However, an estimate of alfalfa forage quality is usually needed before hay is sold or used as feed. Therefore, alfalfa hay quality is estimated using sensory or laboratory analysis. Laboratory evaluation may include either chemical analysis (“wet” chemistry) or near-infrared reflectance spectroscopy (NIRS). Often, both sensory and laboratory analyses are used to evaluate alfalfa hay quality.

ADF and TDN values presented on a laboratory report should not be considered separately; TDN is calculated from ADF.

Sensory Analysis

The visual and physical properties used to evaluate alfalfa hay quality include stage of maturity, leafiness, presence of foreign material, condition, odor, color, and texture.

Maturity

As mentioned in the chapter on harvest management (chapter 11), the stage of maturity when alfalfa is cut is probably the single most important determinant of quality. However, it is difficult for a buyer or broker to determine the maturity of alfalfa once it has been baled. Usually only the presence or absence of bloom can be determined, and this is an inadequate means by which to assess maturity.

Leafiness

Visual inspection involves estimating the leafiness of hay. This is important because leaves are the hay's most nutritious component. On a 100-percent dry-matter basis, leaves contain 27 percent protein and 70 percent total digestible nutrients (TDN); stems at the 10 percent bloom stage contain only 13 percent protein and 45 percent TDN. Leafiness is a function of the alfalfa maturity, variety, weather, and conditions when the hay was raked and baled.

Foreign Material

A sensory inspection involves assessing the presence and amount of foreign material. Foreign material may be weeds, straw, soil, wire, or anything other than alfalfa. Foreign material may be unpalatable or even physically damaging or toxic to livestock. Pay particular attention to unpalatable or toxic weeds (such as foxtails, yellow starthistle, and fiddleneck), since standard laboratory tests do not detect them.

Condition and odor

Dusty hay with excessive leaf shatter results from baling with too little moisture. If hay is moldy, or off-color or has an objectionable odor, its moisture content was too high for baling.

Color

Many people judge alfalfa hay based on its color. The greener it is, they think, the higher its quality. These people give color too much importance; it is not a good indicator of digestibility. Color merely indicates the curing conditions and whether the hay was put up properly.

Texture

Some hay is excessively rough, or "pokey"; other hay is soft and fine textured. Rough-textured hay can be unpalatable and cause intake problems. In severe cases, it can even cause mouth lesions (particularly in horses).

A visual analysis consists of looking at a whole bale or pulling apart a bale and examining hay flakes. Both visual and laboratory evaluation of hay quality are important (Table 13.1) and should be used in combination. Visual inspection is especially useful to detect weeds, mold, and foreign material—all of which cannot be accurately assessed by chemical analyses. Visual inspection is particularly important when purchasing horse hay, since horses are especially sensitive to mold and dust.

Table 13.1. Relative reliability of visual inspection and chemical analysis for evaluating alfalfa quality.

	RELATIVE RELIABILITY	
QUALITY FACTOR	VISUAL INSPECTION	CHEMICAL ANALYSIS
Stage of maturity	Poor	Excellent
Leafiness	Fair	Excellent
Foreign material	Excellent	Poor
Condition	Excellent	Poor
Green color	Excellent	Poor
Texture	Excellent	Poor

Although visual evaluation is useful for describing the physical attributes of alfalfa hay, it cannot be used to estimate the feeding value. Chemical analysis can provide the information necessary for balancing rations and predicting animal performance.

Laboratory Analysis

Much of the alfalfa hay produced in the Intermountain Region undergoes laboratory analysis to estimate its nutritional quality prior to being sold. Values obtained from laboratory analyses are often used to set the price of alfalfa hay. The price differential between "dairy-test" hay and "nontest" hay is usually significant. Therefore, results from quality analyses are extremely important to both the dairy and the hay producer.

Sample Collection

The first step in laboratory analysis is collecting a representative sample. The importance of proper sampling cannot be overemphasized, since it is the primary factor affecting the accuracy of quality analysis. The validity of the testing program rests on obtaining a representative sample that accurately reflects the quality of the entire lot of alfalfa hay.

Quality differences should not result from differences in sampling methods. When sampling, use a coring device rather than an entire flake of hay or a "grab sample." Several core samplers are available for alfalfa hay (Figure 13.2). The inside diameter of the coring device must be no less than $\frac{3}{8}$ inch and no more than $\frac{3}{4}$ inch. The shaft must be long enough to sample at least 12 to 18 inches into the bale. The complexity of coring devices varies widely. A sampler can be a simple shaft,

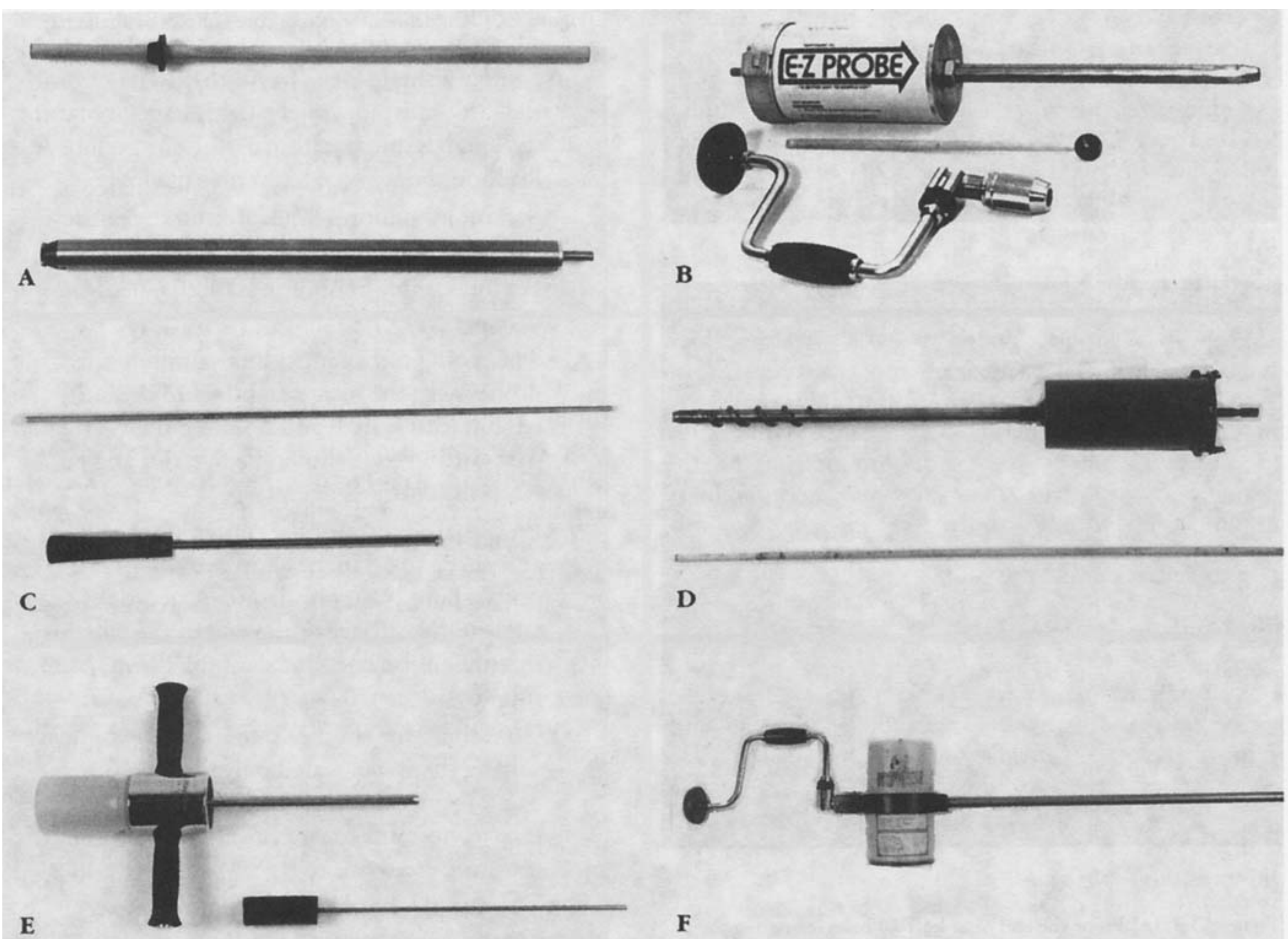


Figure 13.2. Representative coring devices for sampling alfalfa hay bales: (A) Penn State forage sampler, (B) Techni-Serv E-Z Probe, (C) sharpened golf club shaft, (D) Utah hay sampler, (E) Hay Chec hay sampler, and (F) Forageurs hay sampler.

such as a segment of a golf club or ski pole, or a sophisticated device with a sample collection box. (If you use a golf club or ski pole as a sampler, be certain the inside diameter of the shaft is no less than ⅜ inch; many are narrower.) A list of commercially available samplers, their descriptions, and the address of the manufacturer can be found in University of California (UC) Leaflet 21457, *Testing Alfalfa for Its Feeding Value.*

In a test of sampler effectiveness, hay from the same lot was sampled with three different sampling devices. The resulting analyses showed no difference in dry matter or fiber content. The consistency of the findings indicated that none of the three sampling devices over- or underselected any component of the hay. Similarly, a recent test in the Intermountain Region indicated that a sharpened golf club shaft, a Penn State forage sampler, and a Utah hay sampler were equally effective at providing representative samples. However, an auger, or corkscrew-type coring device, selectively sampled leaves over stems. This resulted in analysis of TDN that averaged three percentage points higher than analysis of samples taken by other coring devices. A large quantity of fines in the sample bag usually indicates that the coring device selectively samples leaves.

Quality can vary considerably from bale to bale and even within the same bale. Therefore, to obtain a representative sample, core a minimum of 20 randomly chosen bales per lot—coring 30 to 40 bales would be

(A)

(B)

Figure 13.3. (A) Probe the end of at least 20 bales, centering the coring device in each one. Insert the probe horizontally, 12 to 18 inches deep. (B) Store the entire sample in a sealed polyethylene freezer bag so the laboratory can determine the "as received" moisture content.

Figure 13.4. Guidelines for taking core samples of alfalfa hay.

- Sample a single lot of hay—that is, hay from the same cutting, variety, field, stage of maturity, and harvested within a 48-hour period. A lot should not exceed 200 tons of alfalfa.
- Sample at random. Walk around the entire stack and sample bales at various heights.
- Per lot, sample a minimum of 20 bales (one core per bale).
- The coring device must be a sampling tube, or probe, with the inside diameter of the cutting edge at least ⅜ inch and no more than ¾ inch. The cutting edge should be flat, not angled. Keep the cutting edge sharp.
- Probe bale ends near the center, horizontally, at least 12 to 18 inches into the bale. The probe should enter horizontally at a right angle to the surface of the end of the bale. Be sure the probe does not slant up, down, or sideways.
- Combine core samples into a single sample by storing them in a sealed polyethylene freezer bag. Storing them in plastic will allow laboratory technicians to determine the "as received" moisture content.
- The sample should weigh approximately ½ pound.
- Do not expose the sample to heat or direct sunlight and send to a lab as soon as possible.

better. Probe the stack or lot at various heights and locations around the stack. Probe a bale near the center from either end, inserting the probe horizontally and perpendicular to the surface of the bale (Figure 13.3). Place all samples into one polyethylene freezer bag and seal it so laboratory technicians can determine the "as received" moisture content. Do not divide or subsample prior to grinding; doing so could bias the results if the subsample is taken from the top (where there may be fewer leaves) or bottom (where leaf pieces may settle). Take care not to leave the samples on the dash of your pickup or any other place where they might be subjected to heat or direct sunlight. Send samples to the lab as soon as possible after collection. Figure 13.4 summarizes sampling guidelines.

Testing

Forage quality can be determined either by chemical analyses or by near-infrared reflectance spectroscopy (NIRS). Remember, both methods are only tools to predict animal performance. NIRS is gaining popularity because it is fast and accurate. In chemical analysis, or "wet" chemistry, the alfalfa sample is treated with various chemicals to destroy or isolate certain plant constituents. The remaining plant residues are quantified and used to estimate the feeding value of the alfalfa. The relationship between chemical analysis and animal performance has been established through years of animal-feeding trials.

Figure 13.5 lists the various laboratory analyses that are often performed on alfalfa hay. In addition, the figure describes values used to determine quality. The analyses normally conducted to evaluate alfalfa quality in California include moisture, crude protein (CP), and acid detergent fiber (ADF) tests. Total digestible nutrients (TDN) and other predictions of energy are calculated by using the ADF value. Many nutritionists are increasingly interested in neutral detergent fiber (NDF) analysis, which is useful for predicting intake.

MOISTURE The water content of hay can vary considerably, depending on the environment and the length of time since harvest. Moisture content can have a significant effect on the economic value of the hay on a per-pound basis. The price of hay with a high moisture content should be discounted accordingly. To prevent confusion, laboratories usually report the quality of the hay on an "as received" basis

Figure 13.5. Laboratory analyses to determine the quality of alfalfa.

Crude protein (CP) Estimate of protein based on measurement of both protein and nonprotein nitrogen.

ADF-nitrogen (ADF-N) When alfalfa is damaged by excessive heating, a portion of the crude protein becomes bound and is not available to the animal. The bound protein, calculated from ADF-nitrogen, can be subtracted from the crude protein to estimate the amount of available protein.

Acid detergent fiber (ADF) Measurement of the plant fiber that remains (cellulose and lignin) after an acidic detergent removes more digestible cell components. As ADF increases, the digestibility of alfalfa decreases. ADF is used to calculate many of the energy values that appear in hay analysis reports (TDN, DDM, NEL).

Total digestible nutrients (TDN) Calculated from ADF and used to estimate the energy value of forage. Sum of all digestible organic nutrients (proteins, fiber, fat, nitrogen-free extract). TDN is the most extensively used forage quality value in California for hay-marketing purposes.

Digestible dry matter (DDM) Similar to TDN. DDM is another value calculated from ADF and is an estimate of the energy available in forages. It is used to formulate rations.

Net energy for lactation (NEL) The net energy for lactation is now used more commonly than TDN in dairy ration formulation. It is calculated directly from ADF.

Neutral Detergent Fiber (NDF) This is the fiber that remains after using a neutral detergent to remove the cell contents and pectin. NDF value differs from ADF value in that it includes hemicellulose. NDF analysis is considered to be more useful for predicting intake; the higher the NDF, the lower the intake.

Relative feed value (RFV) Estimates overall forage quality, combining estimates of both digestibility and intake (ADF and NDF). This value is not commonly used in the West.

Calcium (Ca) and phosphorus (P) The quantity of Ca and P, as well as the Ca:P ratio, is important in dairy rations. Alfalfa is a good source of Ca but a rather poor source of P. Knowing the Ca and P concentration in the hay can assist in proper ration formulation.

as well as on a 90- and 100-percent dry-matter basis (Figure 13.6).

CRUDE PROTEIN CP is measured by determining the concentration of nitrogen in the forage sample and converting this figure to protein by multiplying by a factor of 6.25 (the factor derives from the fact that plant protein is generally 16 percent nitrogen). Therefore, CP is not just a measurement of protein—it reflects the presence of other nitrogen-containing compounds, such as amino acids and chlorophyll. Although some laboratories calculate a CP value based on the fiber content of the hay, fiber concentration is a poor indicator of CP. It should not be used in place of the standard method: determining the nitrogen concentration. When alfalfa has been baled with excessive moisture and heat damage occurs, some of the protein may become chemically bound and unavailable. In this case, an analysis for crude protein would overestimate the amount of available protein. An ADF-N analysis (see Figure 13.5) is needed to determine the protein that is unavailable for digestion.

ACID DETERGENT FIBER The energy value of alfalfa hay must be determined indirectly, from its fiber content. Therefore, the ADF and TDN values presented on a laboratory report should not be considered separately; TDN is calculated from ADF. The higher the fiber, the lower the energy value. The most common fiber test is ADF analysis, which has largely replaced the modified crude fiber (MCF) method formerly used in California. The ADF test is preferred over the MCF method because it is faster, easier to run in the laboratory, as accurate as MCF for predicting TDN, and more accurate than MCF for predicting the quality of alfalfa-grass mixtures. The ADF test is the method approved by the National Forage Testing Association. ADF can be converted to TDN by using Table 13.2 or the following equation:

$$TDN\ \% = 82.38 - (0.7515 \times ADF\ \%)$$

In this equation, all constituents are expressed on a 100-percent dry-matter basis. The results of a test can be expressed as the percentage of dry matter in the sample—90 percent or 100 percent, whichever is desired. However, the percentage must be specified to avoid confusion. To convert TDN at 100 percent dry matter to TDN at 90 percent dry matter, multiply by 0.90. Conversely, to convert TDN at 90 percent dry matter to TDN at 100 percent dry matter, divide by 0.90 (or multiply by 1.11).

At 20 core samples per lot, the standard error is typically one percentage point of TDN.

Consistency of Results

Growers, brokers, and dairy producers have been frustrated by variability in laboratory results. Confusion has arisen due to different analysis procedures among regions, states, and individual laboratories. TDN values have varied, although the digestibility of the forage has been the same. Some states and laboratories have used different procedures to determine ADF and

Table 13.2. Relationship between acid detergent fiber (ADF) and total digestible nutrients (TDN) at 100 and 90 percent dry matter (DM).

% ADF		% TDN	
100% DM	90% DM	100% DM	90% DM
20.0	18.0	67.4	60.7
21.0	18.9	66.6	59.9
22.0	19.8	65.8	59.2
23.0	20.7	65.1	58.6
24.0	21.6	64.3	57.9
25.0	22.5	63.6	57.2
26.0	23.4	62.8	56.5
27.0	24.3	62.1	55.9
28.0	25.2	61.3	55.2
29.0	26.1	60.6	54.5
30.0	27.0	59.8	53.8
31.0	27.9	59.1	53.2
32.0	28.8	58.3	52.5
33.0	29.7	57.6	51.8
34.0	30.6	56.8	51.1
35.0	31.5	56.1	50.5
36.0	32.4	55.3	49.8
37.0	33.3	54.6	49.1
38.0	34.2	53.8	48.4
39.0	35.1	53.1	47.8
40.0	36.0	52.3	47.1

Lab Name
Address

Sample No.:	0106
Date received:	6/10/94
Date sampled:	6/7/94
Date reported:	6/13/94

Name:	John Haygrower	Lot I.D.:	Field 4B
Address:	2215 Ranch Lane	Lot size:	120 tons
	High Mountain, CA	Cutting number:	One

		Dry Matter Basis	
I. Laboratory Analyses:	As received	90% DM	100% DM
Dry matter (DM), %	85.5	90.0	100.0
Acid detergent fiber (ADF), %	24.7	26.0	28.9
Crude protein (CP), %	18.6	19.6	21.8
II. Estimated Energy Values (calculated from ADF)			
Total digestible nutrients (TDN), %	51.9	54.6	60.7
Net energy for lactation (NEL), Mcal/lb	0.530	0.558	0.620
Digestible dry matter (DDM),%	56.8	59.8	66.4

III. Hay Quality Rating for This Sample (ADF values on a 100% DM basis)

- [x] Premium (29.0% ADF or less)
- [ ] Good (29.1 to 32% ADF
- [ ] Fair (32.1 to 37% ADF)
- [ ] Low (more than 37% ADF)

Figure 13.6. A hay quality analysis form as provided by a laboratory.

even different mathematical equations to predict TDN from ADF. TDN values reported from laboratories using different methods are not interchangeable. Details of the recommended system for California are printed in UC Leaflet 21457, *Testing Alfalfa for Its Feeding Value.* Confusion has also occurred because forage quality values have been reported at different percentages of dry matter. Some of this confusion can be avoided if the alfalfa industry focuses on the ADF value rather than the predicted TDN and if labs report results on an "as received" 90-percent and 100-percent dry-matter basis.

Differences among laboratories do exist, but these can be minimized by following standard sampling and laboratory procedures. Remember, when splitting a sample to send to two laboratories, grind and mix the sample prior to dividing.

The National Forage Testing Association (NFTA), composed of researchers, extension specialists, hay dealers, and commercial forage-testing laboratories, sponsors a voluntary laboratory certification program to improve the consistency of laboratory results and reduce discrepancies that occur between laboratories. Guidelines for standardized sampling, analysis, and reporting are available. Participating laboratories receive a ground alfalfa sample for analysis once every 3 months. A laboratory is certified when its results fall within an acceptable range for three out of the four annual samples. Using a certified laboratory can help ensure the reliability of the forage quality analysis.

What are typical forage quality values? Table 13.3 lists expected ranges of alfalfa forage quality. Knowing expected ranges of CP, ADF, and TDN for alfalfa at different maturity levels helps a grower assess the credibility of laboratory results. If reported values fall too far from anticipated values, consider disregarding the

Table 13.3. Expected ranges of alfalfa forage quality at various growth stages.[1]

		100% DRY MATTER			90% DRY MATTER		
GROWTH STAGE	DESCRIPTION	% CP	% ADF	% TDN	% CP	% ADF	% TDN
Prebud	>12 in. long, no buds or flowers	25.0–29.0	21.0–25.0	63.5–66.5	22.5–26.0	19.0–22.5	57.0–60.0
Early bud	1–2 nodes with buds, no flowers	22.5–26.0	24.5–28.5	61.0–64.0	20.0–23.5	22.5–25.5	55.0–57.5
Late bud	>3 nodes with buds, no flowers	20.5–24.0	27.0–30.5	59.5–62.0	18.5–21.5	24.5–27.5	53.5–56.0
Early bloom	1–15% bloom	18.0–22.0	29.0–35.0	56.0–60.5	16.0–20.0	26.0–31.5	50.5–54.5
Midbloom	16–85% bloom	15.5–20.0	34.0–37.5	54.0–57.0	14.0–18.0	30.5–34.0	49.0–51.0
Full bloom	86–100% bloom	14.0–17.0	36.5–40.0	52.5–55.0	12.5–15.5	33.0–36.0	47.0–49.5

1. Values are rounded to the nearest 0.5 percent.

results or resubmitting samples for another analysis at the same or a different laboratory.

Limitations of Laboratory Testing

Growers, brokers, and dairy producers should be aware of the limitations on the degree of accuracy that can be achieved with hay quality analysis and not put too much weight on absolute values. For example, there is probably no difference in quality between hay that tests 54.7 and 55.2 percent TDN. Analytical methods are not accurate enough to detect such small differences. Variability exists in the lab results, both with "wet" chemistry and with NIRS analysis; however, the greatest loss in accuracy occurs with sampling. The issue is how well a sample represents the entire lot of hay. At 20 core samples per lot, the standard error is typically one percentage point of TDN. If fewer samples are taken, the error is considerably more. This underscores the need to obtain a representative sample.

Quality testing for forage has advanced significantly in the last decade, and quality analysis is a useful tool for determining the nutrition quality of alfalfa hay and assessing its value. However, growers, brokers, and dairy producers must realize the limitations of forage analysis. Whenever possible, they should assess the value of hay by judging its effect on animal performance, as well as using sensory and chemical tests.

ADDITIONAL READING

Bath, D. L., and V. L. Marble. 1989. *Testing alfalfa for its feeding value.* Oakland: University of California Division of Agriculture and Natural Resources, Leaflet 21457.

Fahey, G. C., Jr., ed. 1994. *Forage quality, evaluation, and utilization.* Madison, WI: American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Hannaway, D. B. and P. J. Ballerstedt. 1988. *Testing the quality of alfalfa hay.* Oregon State University Extension Service. PNW 223.

Holland, O., and W. Kezar, eds. 1990. *Pioneer forage manual: A nutritional guide.* Des Moines, IA Pioneer Hi-Bred International.

Mueller, S. C. 1992. *Production factors affecting alfalfa hay quality.* Proceedings, 22nd California/Arizona Alfalfa Symposium, 84–97. December 9–12, Holtville, CA.