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Quality Forage

Forage Nutrition for Ruminants

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Plants utilized in the feeding of livestock have long been a fundamental link in the food chain. Native grasses supported grazing animals well before man began to domesticate livestock. Forages have always been an extremely important source of nutrients in livestock rations. Additionally, they provide fiber in the ration which enhances proper digestion in forage-consuming animals. Through their conversion into milk and meat products, forages continue to be one of the primary sources of nourishment in the human diet.

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Feed costs represent the single largest expense in most livestock operations. Producing and properly preserving high-quality forages can help reduce the costs associated with feeding concentrates and supplements. Astute producers recognize the economic significance of producing high-quality forage crops and, consequently, place a great deal of emphasis on the production of quality forages.

The primary methods of harvesting and preserving forage crops include silage making, hay making, green chopping and pasturing. Each of these methods of forage harvest and/or preservation has benefits and limitations that make it more desirable than the others for a specific livestock operation. However, any given operation may use each of the methods at varying times, depending on the availability of resources. Producers must review each management practice and evaluate their own production situation to determine which method to use to gain the maximum economic return.

Forage Terminology

Plant structure

Forages have been described as bulky feeds which have relatively low digestibility. However, corn silage is a forage, but can be over 70 percent digestible. Perhaps the best way to understand forages is to look at the properties that make them unique.

Forages contain significant portions of plant cell-wall material. From the standpoint of a forage user, the amount and type of plant cell wall is extremely important because it greatly influences how a particular forage will be utilized by animals to produce meat or milk. A young plant cell has a single outer layer referred to as the primary cell wall. Later, as the plant matures, a second layer is laid down on the inside of the cell. This is called the secondary cell wall.

The secondary wall is thicker and gives the plant cell tensile strength. The main structural components of the primary and secondary walls are the complex

carbohydrates, cellulose and hemicellulose. Together, the primary and secondary cell walls make up a large portion of the forage (40 to 80 percent).

Humans and species with similar digestive tracts have very limited ability to digest plant cell wall compounds. This is unfortunate, as cellulose is one of the most abundant materials on earth. Forage eaters, however, have bacteria and other microbial populations in their digestive tracts than can partially digest these compounds into usable nutrients. Animals that have the ability to utilize forages as the primary portion of their diet do not have the enzymes necessary to digest the cellulose and hemicellulose compounds found in forages. They must rely on the microbial populations within their digestive system.

With advancing growth and maturity, forage cells insert a non-carbohydrate material, known as lignin, into the primary and secondary walls. This complex compound gives the plant additional tensile strength and rigidity. Lignin can be thought of as the primary skeleton of the plant cell. It is important from a nutritional perspective because it is a non-digestible substance and its presence will inhibit the availability of the cellulose and hemicellulose portions of the forage.

A simplified analogy is to think of the young plant cell wall as a wall containing two layers. The initial primary cell wall is the outer brick wall, lacking mortar. The secondary cell wall is like cinder blocks on the inside of the brick wall, but also lacking mortar. The brick and block could both be broken down by the microbial populations within the digestive tract of the animal. Lignin represents the mortar, that is added later, to cement the cell building blocks together. As the plant advances in maturity, more and more lignin is added to the complex of brick and blocks making them more difficult to break down and digest.

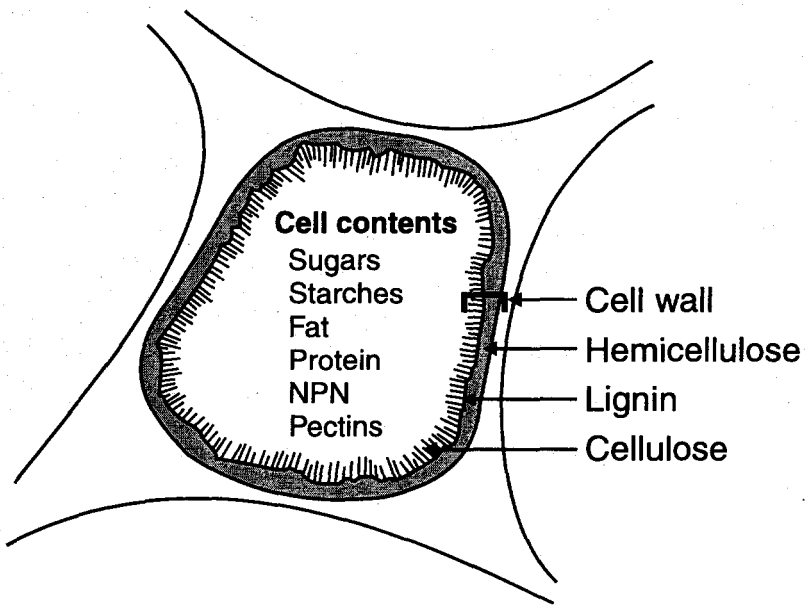

Figure 1. Diagram of a plant cell showing cell wall structure.

Forage evaluation

Visual Appraisal

There are distinct limitations for measuring quality with visual appraisal, such as sight, smell and feel, but they are important tools for evaluating forages. Color, leaf content, stem texture, maturity, contamination from weeds, molds or soil, and observations on palatability are examples of useful visual determinations.

"Wet Chemistry" Analysis

Traditional laboratory methods involve various chemical, drying and burning procedures to determine the major chemical components within the forage. This is the older, well-established method of forage analysis. Wet chemistry procedures are presently the most widely used for forage evaluation in this country. They are based on sound chemical and biochemical principles and take considerably more time to complete than the newer electronic methods. Accurate results are dependent on good sampling techniques when the samples are gathered, proper handling of the samples after collection and good analytical procedures in the laboratory conducting the evaluation.

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The forage analysis is only as good as the sampling, handling and analytical procedures used.

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Proximate Analysis

This wet chemistry set of procedures, analyzes for the following:

- Dry matter content (100 percent minus moisture content)
- Crude protein (total nitrogen is measured)
- Ether extract (lipids and fats)
- Ash (mineral content)
- Crude fiber (cellulose and some lignin)

Using the above analysis, the proximate system estimates the following:

- Nitrogen free extract (sugars, starch and some of the hemicellulose and lignin)
- Total digestible energy (estimate of digestibility)

While the proximate system has some limitations for the analysis of forages, portions of it are widely used today. Most typical forage analyses use the dry matter and crude protein procedures from the proximate system to determine percent dry matter and percent crude protein. Ash (total mineral content) and ether extract are not commonly determined in a typical forage analysis. The original crude fiber analysis has been replaced with the newer detergent analysis.

Dry Matter Determination

Dry matter is the percentage of the forage that is not water. Dry matter content is important because all animal requirements are made on a dry matter basis. It would be impossible to compare different forages without using the percent dry matter as a base line. Dry matter is also very important as the moisture content will give clues as to how a forage will preserve when stored by baling or ensiling.

Protein Analysis

Protein is an important nutrient supplied by forages. In legumes, protein is the primary nutrient supplied and is likely the principle reason a particular forage is being fed. It is important to understand what protein analysis tells about the quantity and quality of the protein present in the forage.

When a laboratory uses wet chemistry, crude protein will most likely be measured by the standard Kjeldahl procedure. This measures total nitrogen which is then multiplied by 6.25 to arrive at the crude protein value for the forage. The 6.25 figure is used because most forages have about 16 percent nitrogen in the protein (100 divided by 16 = 6.25). The crude protein value includes both true protein and non-protein nitrogen compounds. True plant protein is roughly 70 percent of the protein in fresh forages, 60 percent of the total in hay forage and lower than 60 percent in fermented forages. Ruminant animals are able to utilize a portion of both types of protein.

Many laboratories report a digestible protein value. This is a calculated number, such as 70 percent of the crude protein or crude protein minus 4.4. It is an estimate of protein digestibility only and has limited value in formulating rations.

When excessive heating has occurred in the forage, such as in poorly managed silage or hay, a portion of the crude protein may be unavailable. The crude protein analysis gives no indication that excessive heating may have rendered a portion of the protein unavailable. If heat damage is suspected, an analysis for bound protein or unavailable or insoluble protein should be requested. Laboratories typically report the bound protein as ADF-CP, unavailable or insoluble crude protein.

There is always a portion of the crude protein in forages that is unavailable, the percentage of which will increase if heating has occurred. If the bound or insoluble protein is greater than 12 percent of the crude protein, there has been enough heating to reduce protein digestibility. If the bound protein is over 15 percent, there has been extensive heating in the forage.

In formulating rations, the normal amount of bound protein has been taken into account when determining protein requirements for animals. Unless heating in the feed has occurred, the crude protein value can be used in formulation of the ration. If the amount of bound protein is higher than 12 percent, available crude protein (ACP) should be used.

The steps used to calculate the percentage of bound protein and available crude protein (ACP) are:

1. Find the percentage of the crude protein that is bound. Bound protein may be expressed as ADF-CP or Insoluble CP.

   Example:

   Crude Protein = 17.68%
   ADF-CP = 2.36%

   % bound = 2.36 ÷ 17.68 = 13.35%

   Because this value is over 12 percent, it indicates heating has occurred in the forage and available protein should be calculated and used.

2. Calculate % ACP.

   Example:

   % ACP = [CP% x (100 – (% bound – 12%))] ÷ 100

   % ACP = [17.68 x (100 – (13.35 - 12))] ÷ 100 = 17.44

   Note: the ACP value in this case is lower than crude protein, 17.68, because the bound protein value is greater than 12 percent.

   If the forage analysis reports the bound protein as bound nitrogen (ADIN), the bound crude protein can be determined by multiplying by 6.25.

   Example:

   ADIN = 0.29% (dry basis)

   Bound crude protein is: 0.29 x 6.25 = 1.81%

Some laboratories report percent ACP as crude protein minus bound protein. Technically, this is incorrect as it does not account for the normal amount of bound protein in the forage.

Crude Fiber Analysis

Crude fiber determination was the primary analytical procedure used to analyze forage samples for many years. Crude fiber analysis uses alkali and acid treatments to isolate the cell wall residue (crude fiber) that represents undigestible portions of the forage. It was later learned that ruminants could digest a portion of the crude fiber. Even with its faults, the crude fiber system provides valuable information concerning the nutritive value of forages. A modified version of the crude fiber analysis (MCF) that includes the insoluble ash is still used in portions of the country to evaluate alfalfa.

Detergent or Van Soest Method of Cell Wall Determination

A newer wet chemistry method for evaluating the cell wall content of forages was developed in the 1960s by Peter Van Soest at the USDA Beltsville Nutritional Research Facility. This system was developed because it was determined the crude fiber system did not differentiate the components of the cell wall well enough to generate accurate energy estimates over a wide range of forages species and maturities. The crude fiber system was criticized for often underestimating good quality forages and overestimating poor quality forages. Figure 2 shows how the crude fiber and the newer detergent systems fractionate forages.

The Van Soest or detergent system of forage analysis is now the most common way to partition forages. The forage sample is boiled in a special detergent at a neutral pH of 7.0. The material is then filtered. The soluble portion contains these highly digestible cell contents:

- sugars
- starch
- pectins
- lipids (fat)
- soluble carbohydrates
- protein
- non-protein nitrogen
- water soluble vitamins and minerals

Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF)

The insoluble portion of the forage (neutral detergent fiber) contains the cellulose, hemicellulose, lignin and silica. It is commonly referred to as the cell wall fraction. Neutral detergent fiber has been shown to be negatively correlated with dry matter intake. In other words, **as the NDF in forages increases, animals will be able to consume less forage.** NDF increases with the advancing maturity of forages. A better prediction of forage intake can be made using NDF; therefore, better rations can be formulated.

The fraction of the forage cell wall that is most commonly isolated and reported is the acid detergent fiber (ADF). This may be the most important determination of the forage analysis.

Acid detergent fiber is the portion of the forage that remains after treatment with a detergent under acid conditions. It includes the cellulose, lignin and silica (Figure 2). Acid detergent fiber is important because it has been shown to be negatively correlated with how digestible a forage may be when fed. As the ADF increases, the forage becomes less digestible. Acid detergent fiber is sometimes misinterpreted as indicating the acid content of fermented forages. The term acid detergent fiber has nothing to do with the acid content of a forage. The name is derived from the procedure used to determine the cellulose and lignin content.

Lignin, the indigestible non-carbohydrate component that decreases cellulose and hemicellulose availability, can be determined by further treatment with a stronger acid. Figure 3 shows a schematic of the detergent system of a forage analysis. Table 1 classifies the forage fractions using the Van Soest method. The average cell contents and cell wall fractions for forages common to our area are listed in Table 2.

Table 1. Classification of forage fractions using the Van Soest method.

Fraction	Components included	Nutritional Availability	
		Ruminant	Non-ruminant
Cell contents	• sugars, starch, pectin	complete	complete
	• soluble carbohydrates	complete	complete
	• protein, non-protein N	high	high
	• lipids (fats)	high	high
	• other solubles	high	high
Cell Wall (NDF)	• hemicellulose	partial	low
	• cellulose	partial	low
	• heat damaged protein	indigestible	indigestible
	• lignin	indigestible	indigestible
	• silica	indigestible	indigestible

Source: Van Soest, JAS 26:119.

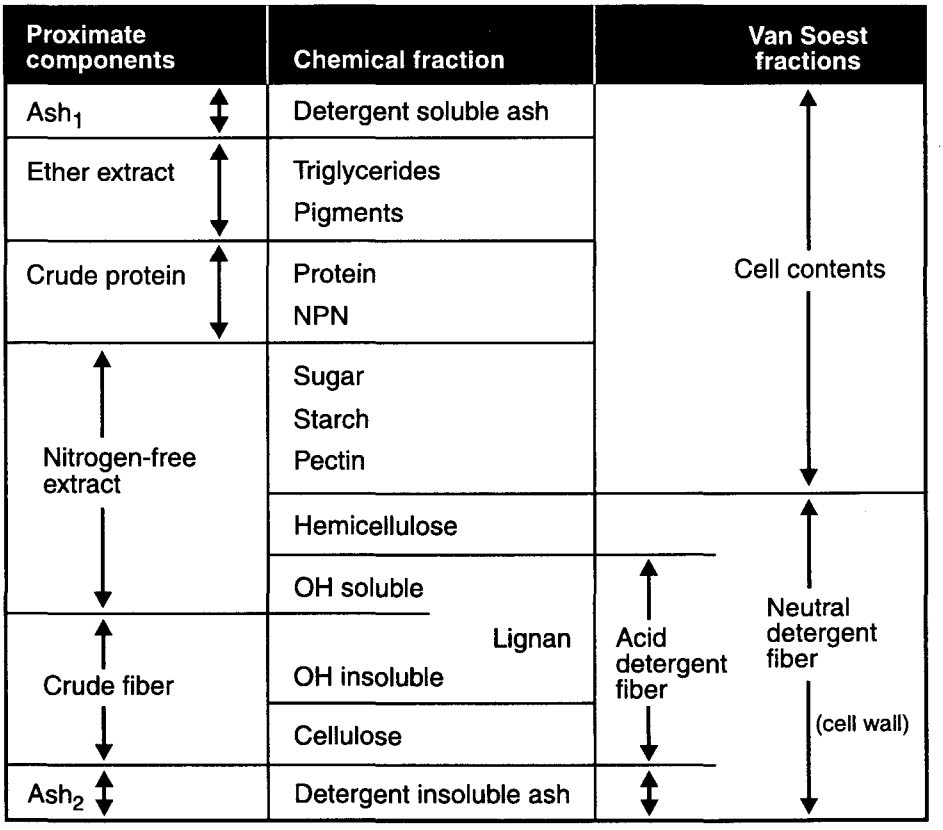


Figure 2. Fractions of feed dry matter.

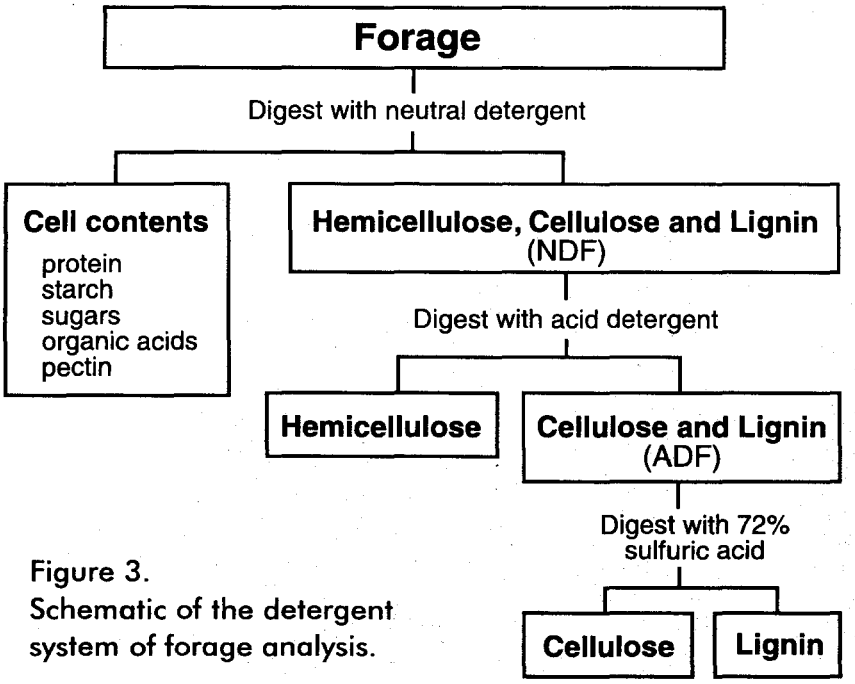


Figure 3.
Schematic of the detergent system of forage analysis.

Table 2. Average cell contents and cell wall fractions in common forages.

Forage	Cell Contents	NDF	ADF	CF	Lignin
Percent, Dry Matter Basis					
Alfalfa					
late vegetative	60	40	29	22	7
early bloom	58	42	31	23	8
mid-bloom	54	46	35	26	9
full bloom	50	50	37	29	10
Red clover	44	56	41	9	10
Birdsfoot trefoil	53	47	36	31	9
Brome					
late vegetative	35	65	35	30	4
late bloom	32	68	43	37	8
Orchardgrass					
mid-bloom	32	68	41	33	6
late bloom	28	72	45	37	9
Sorghum-sudangrass	32	68	42	36	6
Timothy					
late vegetative	45	55	29	27	3
mid-bloom	33	67	36	31	5
late bloom	32	68	55	31	7
Corn silage					
stover	32	68	55	31	7
well eared	49	51	28	24	4
few ears	47	53	30	32	5

Source: United States-Canadian tables of feed composition, third revision. 1982.

Neutral Detergent-Soluble Carbohydrates (NDSC)

The carbohydrates soluble in neutral detergent include the most digestible portion of the plant and are the most difficult to describe nutritionally.

In contrast to non-structural carbohydrates (NSC) also referred to as non-fiber carbohydrates (NFC), the carbohydrates in question are actually "neutral detergent-soluble carbohydrates" (NDSC).

The NDSC include both structural and fiber carbohydrates (Figure 4). As a class, NDSC are highly digestible (see Van Soest, Figure 3) and rapidly fermented. However, they are a compositionally diverse group, which has tended to preclude their direct measurement by chemical analysis.

NDSC is calculated as the difference between NDF and non-carbohydrate fractions by the equations:

100 – (crude protein + NDF + ether extract + ash)

-or-

100 – ((crude protein + (NDF – NDIN) + ether extract + ash))

The second equation corrects for protein in the NDF and avoids subtracting the protein twice. Because it is calculated by difference, all of the errors from the component analyses accumulate in NDSC.

The source of crude protein within a feed may be a source of error in the NDSC calculation. Crude protein is simply an estimation of protein mass arrived at by multiplying nitrogen content

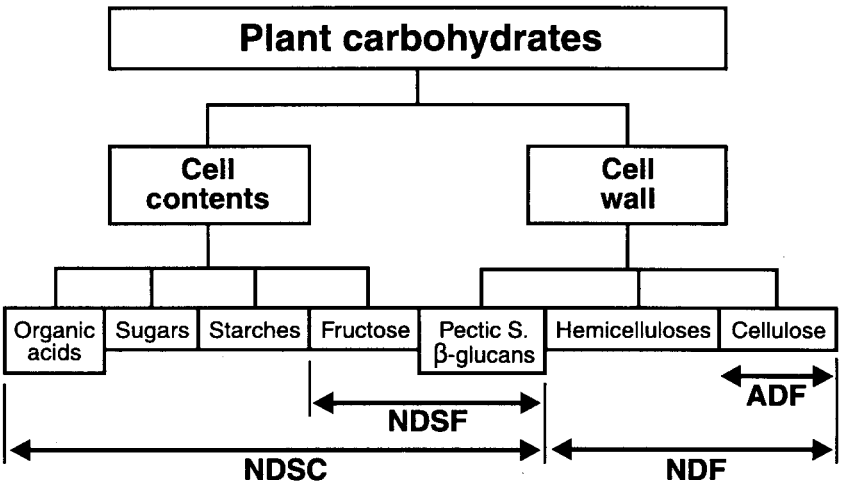
by 6.25. When the nitrogenous compounds present are not one-sixteenth nitrogen, factors other than 6.25 may be appropriate. However, there is no practical way to determine the correct multiplier. The effect of miscalculation of crude protein mass on NDSC calculation is of special concern with feeds high in non-protein nitrogen.

One of the greatest challenges to using NDSC in ration formulation is its diversity of components. The NDSC includes organic acids, sugars, disaccharides, oligosaccharides, starches, fructans, pectic substances, ß-glucans and other carbohydrates soluble in neutral detergent.

Different carbohydrates predominate in the NDSC of different feeds. Beyond their composition, these carbohydrates also vary in their digestion and fermentation characteristics (Table 3).

Organic acids, such as acetate and lactate, do not support microbial growth to the extent of other carbohydrates.

The rate of starch fermentation in the rumen is highly variable and changes with the processing method, source and other ration components. Pectic substances support a microbial yield similar to starch, but their fermentation is depressed at low pH.



Pectic S = pectic substances; ADF = acid detergent fiber; NDF = neutral detergent fiber; NDSC = neutral detergent-soluble carbohydrates; NDSF = neutral detergent-soluble fiber.

Figure 4. Carbohydrate composition of chemically analyzed fractions.

Table 3. Characteristics of neutral detergent-soluble carbohydrates (NDSC).

NDSC Fraction	Predominant Composition	Digestible by Mammalian Enzymes[1]	May Ferment to Lactic Acid[1]	Fermentation Depressed at Low pH[1]	Common Sources
Organic acids	acetate propionate, lactate, butyrate	yes	no	no	silage, feed, additives, whey
Sugars and disaccharides	glucose, fructose, sucrose (glucose + fructose)	yes	yes	no	molasses, citrus pulp, sugar beet pulp
Starch	glucose	yes	yes	no difference	corn and small grain products, bakery waste, potatoes
Fructans	fructose	no	yes	unknown	temperate cool season grasses, Jerusalem artichoke
Pectic substances	galacturonic acid, arabinose, galactose, rhamnose, etc.	no	no	yes	legume forages, citrus pulp, beet pulp, soybean hulls
ß-glucans	glucose	no	no	yes/unknown	small grains

[1] Relative to starch.

Reference: M.B. Hall, University of Florida

Thus far, differences in NDSC among feeds have been used in a qualitative fashion for ration formulation because there was no practical way to measure the component carbohydrates. Recent work offers a way of analyzing feeds to separate neutral detergent-soluble fiber from starches, sugars and organic acids. Although this improves upon the current situation, more work needs to be done to determine how to optimally formulate rations using the different fractions, and how to separate organic acids from sugars and starches to better predict nutrients available to the animal.

Mineral Analysis

Forage analyses typically report the content of major minerals. The minerals typically determined are calcium and phosphorus. In laboratories using wet chemistry, atomic absorption and colorimetric procedures are most commonly used to determine the mineral content of the forage.

Near Infrared Reflectance Spectroscopy (NIRS) Analysis

Near infrared reflectance spectroscopy is a rapid and low-cost computerized method to analyze forage and grain crops for their nutritive value. Instead of using chemicals, as in conventional methods, to determine protein, fiber, energy and mineral content, NIRS uses near-infrared light.

This method of analysis involves the drying and grinding of samples which are then exposed to infrared light in a spectrophotometer. The reflected infrared radiation is converted to electrical energy and fed to a computer for interpretation. Each major organic component of forages (and grain) will absorb and reflect near-infrared light differently. By measuring these different reflectance characteristics, the NIRS unit and a computer determine the quantity of these components in the feed.

The procedure is similar to the human ability to visually distinguish color when light strikes a material that absorbs some wavelengths and reflects others.

The detection of specific nutrients is possible because reflectance spectra from forage samples of established nutrient values (by wet chemistry procedures) are programmed into the computer. When a similar feed sample is evaluated by NIRS, the computer compares the wavelength reflections caused by the sample, and matches them to previously tested samples.

The NIRS method of determining forage nutritional content is very rapid (25 times faster than conventional laboratory procedures) and less expensive than wet chemistry methods. Accuracy depends on good sample collection, storage and consistent drying, grinding and mixing of samples prior to analysis. The calibration set that is used must be developed from an adequate number of wet chemistry samples, similar to those being analyzed. Without proper calibration, the NIRS analysis can have serious error.

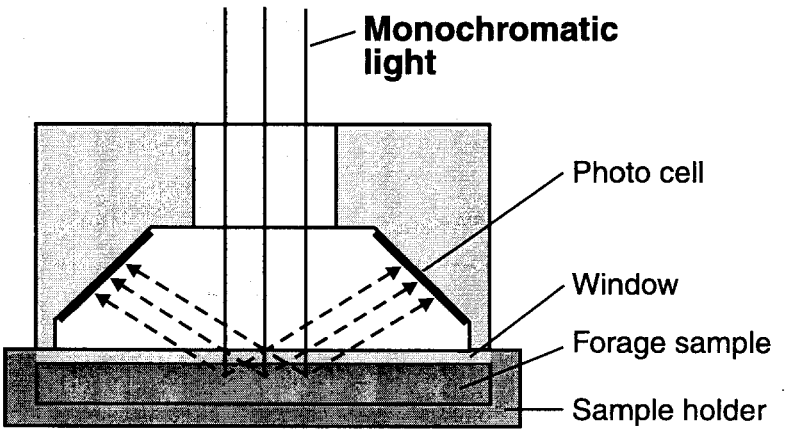


Figure 5. Diagram of how NIRS reads a prepared plant sample.

The typical forage analysis generated with NIRS is similar to that using proximate and detergent analysis.

In addition, NIRS typically reports bound protein, available crude protein, potassium and magnesium values.

In Vitro and In Vivo Disappearance Evaluation

In vivo (in animal) and in vitro (in glass or in test tube) procedures are seldom used for farm forage analysis. They are, however, commonly used by scientists to evaluate forage quality. Most often, dry matter disappearance in a specific period of time is measured and this value will indicate how digestible a forage may be. The term in situ (in bag) may be used to describe the procedure where small nylon bags containing samples of forage are placed in the rumen of live animals consuming similar diets to the forage being evaluated. This is done through a sealed external opening into the rumen of an animal, called a canula.

In vitro is usually a two-step procedure done in test tubes. First the forage sample is digested using rumen fluid from a donor animal to simulate rumen digestion. The sample is then digested in an enzyme solution to simulate digestion in the small intestine. Both in situ and in vitro are excellent techniques for forage evaluation when more expensive and time-consuming digestion or feeding trials are not possible.

Digestion trials are an excellent way to evaluate forages or other feeds for nutrient availability. In this procedure, the forage is fed to several animals. The amount of forage fed and feces produced in a 10 to 14 day period is recorded and sampled for analysis.

An estimate of digestibility can then be calculated.

((dry matter intake – dry matter in feces) ÷ dry matter intake) x 100 = apparent dry matter digestibility

Example: In a digestion trial using six animals, the average feed intake and fecal production were:

((252 - 93.5) ÷ 252) x 100 = 62.9% apparent dry matter digestibility

Because an analysis can be done on both the feed and the feces, it is possible to determine the digestibility for each nutrient in the feed. For example, the protein digestibility could calculate to be 75 percent digestible while the cell wall fractions may only be 59 percent digestible. In scientific research this procedure is followed to determine total digestible nutrients (TDN). The actual formula is:

% digestible crude protein +
% digestible crude fiber +
% digestible starch and sugars +
% digestible fats x 2.25 = % TDN

The fats are multiplied by 2.25 because they contain that much more energy per unit weight.

Total digestible nutrients may be estimated when the forage analysis is determined using the proximate analysis. This is done using average digestion numbers from previous digestion trials.

While TDN values are common on forage analysis reports, TDN is not commonly used in ration formulation because it does not account for all the losses that can occur in the fermentation and metabolism when forages are fed. These losses can be large in forages, so improved energy estimate systems have been developed.

Energy terminology

Consumed forage can be thought of as a fuel and the animal that consumes it, a vehicle. No vehicle is 100 percent efficient at burning fuel. No animal uses 100 percent of the forage to produce the products we derive from them.

By accounting for losses during digestion, absorption and utilization, better predictions of the usable energy content of feeds can be made. It is very common to see the terms net energy-maintenance (NE_M), net energy-gain (NE_G) and net energy-lactation (NE_L) on laboratory or NIRS forage reports. These terms are commonly used in formulating today's rations. Figure 6 shows the losses subtracted out to arrive at these energy terms.

The total energy content of a feed can be determined by bomb calorimetry (completely burning) the sample and measuring the heat produced to obtain the gross energy value of the feed. It does not, however, indicate how digestible the feed is. For example, wood chips and corn grain have about the same gross energy value but if both were fed, the digestibility would be very different. Table 4 compares some common forages.

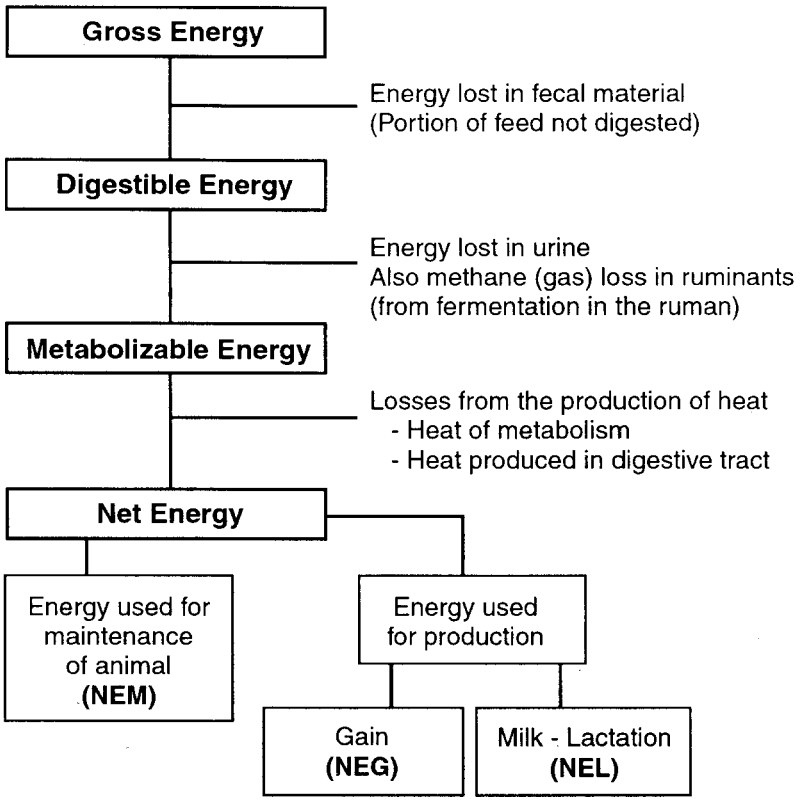


Figure 6. Energy losses when forages are fed.

Table 4. Four forages showing total digestible nutrient and net energy values.[1]

		Net Energy, Mcal Per Pound		
Forage	% TDN	Maintenance	Gain	Lactation
Bermudagrass, 43-56 day growth	43	0.33	0.09	0.42
Alfalfa hay, full bloom	55	0.52	0.26	0.56
Alfalfa hay, late vegetative	63	0.64	0.38	0.65
Corn silage, well eared	70	0.74	0.47	0.73

[1]All values on a dry matter basis.
Source: NRC, Nutrient Requirements of Dairy Cattle, 1989, 2001.

Important Points

1. Net energy values for forages are best for ration formulation because they account for the major losses in digestion and utilization of the feed.
2. There are three net energy values for each feed because animals use feeds with different efficiencies, depending on how the energy is being utilized. Net energy-gain is the least efficient and will have the lowest value. NE_M and NE_L are utilized with about equal efficiencies. In most dairy formulations, the same value is used for both NE_M and NE_L.
3. Total digestible nutrients, which are calculated from digestion trials, do not account for all the losses. Forages tend to have a large loss of energy due to fermentation in the rumen of the animal. Unless it is below the thermal neutral zone of the animal, this heat loss represents total loss to the animal. For this reason, TDN tends to overestimate the energy value of forages. Therefore, net energy values, not TDN, are normally used in ration formulation.
4. Laboratory digestibility and net energy values are not produced from digestion trials or metabolism studies. The feeding value of forges has been shown to be negatively associated with cell wall contents (as the ADF and NDF values go up, energy values decrease). Because of this, energy values, estimates of digestibility and relative feed values reported on laboratory analysis are calculated using the ADF content in the forage. Neutral detergent fiber content is used to estimate the amount of forage an animal will be able to consume.

The fact that ADF and NDF values are used to generate many of the relative feeding values further emphasizes the importance that cell wall content has on animal performance.

Forage Terms

Digestible Dry Matter (DDM)

Many forage analyses will include a value called digestible dry matter. While different laboratories may use different formulas to calculate this value, one common formula is:

88.9 – (0.779 x % ADF) = %DDM

Example:

If % ADF = 31%:
88.9 – (0.779 x 31) = 64.75%

Dry Matter Intake (DMI)

Feeding studies have shown that as the percent of NDF increases in forages, animals consume less. Therefore, percent NDF can be used to estimate dry matter intake. The formula used for the calculation is:

120 ÷ %NDF = DMI
(as a percent of body weight)

Example:

NDF value for a forage is 40%: 120 ÷ 40 = 3.0% of body weight DMI

Relative Feed Value (RFV)

The dry matter intake potential (DMI) may not be reported as such, but may be used to calculate a term called relative feed value (RFV). This combines dry matter intake and the digestible dry matter (DDM) values of the forage.

(%DDM x %DMI) ÷ 1.29 = RFV

Example:
From the previous examples
DDM = 64.75%, DMI = 3.0%

(64.75 x 3.0) ÷ 1.29 = 151

Relative feed value has no units, but is a way to compare the potential of two or more like forages for energy intake. Forages with NDF values of 53 percent and ADF values of 41 percent represent the value of 100.

Forages with values greater than 100 are of higher quality. If a forage has a value lower than 100, it is lower in value compared to the forage with 53 percent NDF and 41 percent ADF. Note that the forage with an RFV of 100 would not be considered excellent quality forage. Dairy producers with high producing cows often require 150 or greater.

Relative feed values do not take into account the protein content of the forage. Protein content has to be evaluated separately. Table 5 shows forages with different relative feed values and expected CP levels.

Relative Feed Quality (RFQ)

Recently approved, Relative Feed Quality (RFQ) is an improved version of RFV. Developed by the University of Wisconsin, it adds measures for fiber digestibility as well as quantity.

The proposed new RFQ index, originally called digestible Relative Feed Value (dRFV), will replace RFV which was implemented in 1978. Although widely used, it has become apparent that hay lots with identical RFV scores don't necessarily produce the same amount of milk. As a result, the RFV index has come under increasing scrutiny as scientists have learned more about fiber digestibility.

Table 5. Relative feed values of various forages.

Forage	CP	ADF	NDF	RFV
		%		
Alfalfa, pre-bud	23	28	38	164
Alfalfa, bud	20	30	40	152
Alfalfa, mid-bloom	17	35	46	125
Alfalfa, mature	15	41	53	100
Alfalfa-grass, bud	19	30	45	135
Alfalfa-grass, mid-bloom	15	38	55	100
Alfalfa-grass, mature	12	42	52	101
Brome, late vegetative	14	35	63	91
Brome, late bloom	8	49	81	58
Bermudagrass, early	12	32	70	85
Bermudagrass, late	8	43	78	66
Corn silage, well eared	9	28	48	133
Corn silage, few ears	8	30	53	115
Cornstalks	6	43	68	76
Sorghum-sudangrass, vegetative	15	29	55	112
Surghum-sudangrass, headed	8	40	65	83
Wheat straw	4	54	85	51

A forage's energy content has a lot to do with the digestibility of its fiber, and forages similar in most other quality parameters can vary widely in fiber digestibility. The current RFV formula uses ADF to estimate energy content. However, ADF only explains about 55 percent of the variation in the digestibility of a forage.

The proposed RFQ will predict both the energy content and potential intake of forages, just as RFV does. The difference: with RFQ, NDF digestibility will be included in both calculations. That's because digestibility impacts the energy content of a forage as well as the amount animals will eat. To avoid confusion and ensure broad acceptance of the switch to RFQ, the scientists kept the numbers and scale the same as with RFV. Dairy-quality hay will still score above 150, for example.

On average, alfalfa will get the same scores as it does now. Individual samples, though, may differ by up to 50 points when evaluated by RFQ instead of RFV. But the results will more accurately reflect the forage's true value.

In general, grasses will get higher scores under RFQ. They tend to be high in NDF, so they score too low when all fiber is assumed to be equally digestible. Changing RFV likely will broaden its applicability.

Presently, RFV is appropriate only for alfalfa and cool-season grasses, though it often is used more widely.

The new index probably can be used on corn silage and perhaps other types of forage too.

New RFQ Index

RFQ = (TDN x intake ÷ 16.8) + 39.2

Where:

TDN_{ix} = dNFC + dCP + (dFA x 2.25) + dNDF – 7

= [(NFC x .98) + (CP x .93) + (FA x .97 x 2.25) + (NDF x NDFD ÷ 100)] – 7

CP = crude proteinNDF = neutral detergent fiber

NDFCP = crude protein remaining in NDF residue (average 3.8 for alfalfa/grasses)

FA = ether extract – 1

NFC = 100 – (CP ÷ NDF + ether extract + ash – NDFCP)

NDFD = neutral detergent fiber digestibility = grams NDF digested in 48 hours per gram NDF

Intake = [(NDFD – lab average NDFD) x 0.374] + base intake

Base intake = 0.0086 x 1,350 ÷ (NDF ÷ 100)

Predictive Equations for Alfalfa Quality

Predictive Equations for Alfalfa Quality (PEAQ) is a method to predict the forage quality of standing alfalfa. It was developed by agronomists at the University of Wisconsin - Madison.

The two equations predict ADF and NDF when the height of the tallest stem is measured and the maturity stage of the most advanced plant is determined. The equations have been validated not only in Wisconsin but also in numerous other environments from California to New York.

Because regression equations are difficult and somewhat time-consuming in a production field situation, tables have been developed using computer spreadsheet programs that help make for rapid in-field estimates of NDF or Relative Feed Value (RFV).

Additionally, several seed companies have developed "PEAQ sticks" that can easily be used to determine plant height and forage quality.

The original "five maturity stage" system used with PEAQ has been simplified to a "three maturity stage" system without a loss of precision.

Estimating alfalfa RFV in the field using PEAQ

Step 1: Choose a representative two-square-foot area in the field.

Step 2: Determine the most mature stem in the two-square-foot sampling area using the criteria shown in Table 5.

Step 3: Measure the length of the tallest stem in the two-square-foot area. Measure it from the soil surface (next to the plant crown) to the tip of the stem (NOT to the tip of the highest leaf blade). Straighten the stem for an accurate measure of its length. The tallest stem may not be the most mature stem.

Step 4: Based on the most mature stem and length of the tallest stem, use Table 5 to determine estimated RFV content of the standing alfalfa forage.

Step 5: Repeat steps 1 to 4 in four or five representative areas across the field. Sample more times for fields larger than 30 acres.

Note: *This procedure estimates alfalfa RFV content of the standing crop. It does not account for changes in quality due to wilting, harvesting and storage. These factors may further lower RFV content by 15 to 25 units, assuming good wilting and harvesting conditions. This procedure is most accurate for good stand of pure alfalfa with healthy growth.*

Many state and county Extension staff are using PEAQ along with other methods to help farmers predict the optimum harvest time for alfalfa.

This has proved especially useful for first cutting.

Predicting relative feed value of first cut alfalfa.

Height of Tallest Stem (from soil surface to step tip)	Stage of Most Mature Stem				
	Late Vegetative (<12", no buds visible)	**Early Bud** (1 to 2 nodes with visible buds)	**Late Bud** (more than 2 nodes with visible buds)	**Early Flower** (1 node with 1+ open flower(s))	**Late Flower** (2+ nodes with an open flower)
Inches	**Relative Feed Value**				
16	234	220	208	196	186
17	229	215	203	192	182
18	223	211	199	188	178
19	218	206	195	184	175
20	213	201	191	181	171
21	209	197	187	177	168
22	204	193	183	173	165
23	200	189	179	170	161
24	196	185	175	167	158
25	191	181	172	163	155
26	187	178	169	160	152
27	184	174	165	157	150
28	180	171	162	154	147
29	176	167	159	151	144
30	173	164	156	148	141
31	169	161	153	146	139
32	166	158	150	143	136
33	163	155	147	140	134
34	160	152	145	138	132
35	156	149	142	135	129
36	154	146	139	133	127
37	151	144	137	131	125
38	148	141	134	128	
39	145	138	132	126	121
40	142	136	130	124	118
41	140	133	127	122	116
42	137	131	125	120	114
43	135	129	123	118	113
44	132	126	121	116	111
45	130	124	119	114	109
46	128	122	117	112	107
47	126	120	115	110	105
48	123	118	113	108	103

Example: In a two-square-foot area, the most mature stem has three nodes with visible buds but no open flowers (Late Bud). The tallest stem measures 31 inches from the soil surface. Estimated RFV is 153.

Formulas Used in Forage Analysis Reports

Various laboratories may use different formulas for reporting calculated values for forages. Some of the more common ones are shown.

It should be noted that because the same formulas are not used by all laboratories, it may not be possible to compare the values from one laboratory with those of another.

1. **Estimating Percent Digestible Protein (DP):**

   Corn silage: % DP = (% crude protein x 0.908) – 3.77
   -or-
   = crude protein x 0.70

   Alfalfa: % DP = % crude protein – 4.4
   -or-
   = % crude protein x 0.72

2. **Estimating Percent TDN:**

   Legumes and grasses: = 88.9 – (0.79 x ADF%)

   Corn silage: = 87.84 – (0.70 x ADF%)

3. **Estimating Net Energy-Lactation, Mcal/lb:**

   Alfalfa: = 1.044 – (ADF% x 0.0123)

   Grasses: = 1.50 – (ADF% x 0.0267)

   Alfalfa – grass mixtures: = 1.044 – (ADF% x 0.0131)
   -or-
   = (TDN% x 0.1114) - 0.054

4. **Estimating Percent Digestible Dry Matter (DDM):**

   % DDM = 88.9 – (ADF% x 0.779)

5. **Estimating Dry Matter Intake as a Percent of Body Weight (DMI):**

   % DMI = 120 ÷ % NDF

6. **Relative Feed Value (RFV):**

   RFV = (%DDM x %DMI) ÷ 1.29

7. **Relative Feed Quality (RFQ):**

   RFQ = (TDN x intake) ÷ (16.8 + 39.2)

Other publications in the Quality Forage series

- ➤ AS-1251 Intrepreting Composition and Determining Market Value
- ➤ AS-1252 Haylage and Other Fermented Forages
- ➤ AS-1253 Corn Silage Management
- ➤ AS-1254 Silage Fermentation and Preservation
- ➤ AS-1255 Storage, Sampling and Measuring
- ➤ AS-1256 Stressed-Damaged Crops

References

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Replaces AS-991 "Know Your Forages"

For more information on this and other topics, see: www.ag.ndsu.nodak.edu

AS-1250

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