MN 2500 AGFO-2637

AGRICULTURAL EXTENSION SERVICE
UNIVERSITY OF MINNESOTA

AG-FO-2637
1985

USING FORAGE TEST RESULTS IN DAIRY RATIONS

Jim Linn, Extension Animal Scientist-Dairy Nutrition
Neal Martin, Extension Agronomist-Forage

UNIVERSITY OF MINNESOTA
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AUG 31 1987
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The feeding value of a forage is determined by nutrient and chemical constituents, intake potential, digestibility, and efficiency with which absorbed nutrients are converted into animal products. The right forage analyses, accurately conducted, can provide good estimates on forage feeding values, which allows for more precise formulation of dairy rations and greater farm profitability.

The recommended minimum forage analyses for dairy producers are: dry matter (DM), crude protein (CP), acid detergent fiber (ADF), calcium (Ca), and phosphorus (P). If stored forages have heated or caramelized excessively, an adjusted CP analysis is needed. Energy values (TDN or net energy) can be calculated from fiber analyses along with a DM digestibility (DDM) and relative feed value (RFV).

Samples submitted for analysis must be representative of the forages being fed. Samples which do not represent forages will result in misleading feeding values and increased production costs.

Using Forage Test Results

Because the quality of forage produced can not always be controlled, it is important to test forages for feeding value regularly. Test information can be used to:

1) Formulate nutritionally balanced rations for livestock.
2) Develop feed inventories based on quality and quantity of forages available.
3) Evaluate forage management practices (growing, harvesting, and storing).
4) Determine equitable prices for forages based on feeding value.

Converting Forage Test Results to Dry or Wet Basis

Forage test results can be reported on an as-fed, air-dry, or DM basis. The definitions of these bases are listed below:

Basis	Definition
As-fed, Wet or Fresh	Nutrients expressed on these bases represent the nutrient content of the feed as it is fed. Nutrient values expressed on these bases are lower than when expressed on either an air-dry or DM basis as the water or moisture content of the feed dilutes out the nutrient content.
Air-Dry	Feeds are assumed to contain 10 percent moisture or 90 percent DM.
Dry Matter (DM)	Moisture free (0 percent) or 100 percent dry basis. All moisture has been removed and nutrient concentration is that contained in the DM portion of the feed.

Converting forage nutrients to a DM basis can be done using the following formula:

$$\text{Nutrient (DM Basis)} = \frac{\text{Nutrient (as fed or wet basis)} \times 100}{\text{DM\%}}$$

Nutrient values should be on a DM basis for use in formulating livestock rations. Also, equations for calculating energy or other components from nutrient analysis require nutrients to be expressed on a DM basis. The following example shows how to convert test results from as-fed to DM basis:

Corn Silage Analysis (as-fed)

Moisture—62%
Crude protein—3.1%

Step 1—Determine DM content.

$$\text{DM\%} = (100 - \text{\% Moisture})$$
$$38\% = (100\text{-}62)$$

Step 2— Use above equation to convert CP analysis to a DM basis.

$$\text{CP\% (DM basis)} = \frac{3.1\% \times 100\%}{38\%}$$
$$\text{CP\% (DM basis)} = 8.16$$

Units for Expressing Nutrients

Percent (%) = Number of parts per 100 parts.
i.e. 10% = 10 lb. per 100 lb.

Parts per million (ppm) = Number of parts per million parts.
i.e. 1 ppm = 1 lb. per 1,000,000 lb.

Common Units and Measures

1 pound = 454 grams
2.2 pounds = 1000 grams = 1 kilogram
1 ounce = 28 grams
1 gram = 1,000 milligrams
1% = 10,000 ppm
1 milligram/kilogram = 1 ppm

Interpreting and Applying Forage Test Results

Dry Matter (DM)

DM is determined by subtracting percent moisture from 100 (DM% = 100 – % Moisture). Knowing DM content of forages is important for:

1. Ration formulation, comparing nutrient contents between forages, and to calculate animal digestibility parameters.
2. Nutrients are contained in the DM portion of forages. Cows of similar size and production level consume similar amounts of DM. Thus, nutrient intakes are easily determined.
3. Forage DM contents are potential indicators of abnormal conditions during storage. Forages which are ensiled too dry or hay baled too wet can heat, reducing protein availability and/or become moldy. Ensiling forages too high in moisture can result in excessive losses through seepage and undesirable fermentations.

Suggested moisture ranges for forages

Forage	Moisture %
Hay—baled	Less than 20
Haylage—stave silo	50 to 60
sealed silo	45 to 55
Corn Silage	62 to 68

Crude Protein (CP)

Mixtures of true proteins, composed of amino acids, and non-protein nitrogen make up the CP content of forages. The CP content of forages is determined by measuring the amount of nitrogen (N) and multiplying by 6.25. The general term "protein" refers to CP.

Crude protein is an essential nutrient for dairy cows and is only second to energy in terms of quantity required and importance. When harvested early and stored properly, legume and legume-grass forages are excellent sources of protein. The average CP content of some common forages is listed in table 1.

Adjusted Crude Protein (ACP)

Excess moisture in hays and too little moisture in the presence of too much oxygen in haylages result in heating and caramelization of forages. Some true proteins become tied up with carbohydrates during the heating process which makes them unavailable to the animal. Heat damaged forages are characterized by being brown to black in color and having a sweet caramel-tobacco aroma. Cows often relish heat damaged forages because sugars become condensed and turn into syrup during heating.

The amount of unavailable or heat damaged protein in forages can be measured either by determining the amount of CP or N in the ADF fraction or by digesting the feed in pepsin, an enzyme found in the intestine of animals. The analysis for N in the ADF fraction is commonly referred to as ADF-N or acid detergent insoluble N (ADIN), whereas the pepsin analysis is usually referred to as pepsin insoluble N. Bound protein is another term sometimes used in referring to heat damaged proteins.

Adjusted CP (ACP) is the amount of CP available to an animal for utilization after being corrected for unavailable protein. In most forages, 12 percent or less of the CP is in the ADF fraction or unavailable and is considered normal. For example, alfalfa containing 20 percent CP will have 2.4 percent CP or less in the ADF fraction. When the percentage of CP in the ADF fraction increases above 12 percent, this indicates harvesting and storage conditions were not ideal and some reduction in CP availability has occurred. The higher the percent CP in the ADF, the more extensive is the reduction. Use ACP values in formulating livestock rations.

Table 1. Average nutrient composition of some common Minnesota forages.

Forage	CP (%)	NDF (%)	ADF (%)	ADL (%)	CF (%)	NE_L (Mcal/lb)	TDN (%)	Ca (%)	P (%)
	100% DM basis								
Alfalfa—									
Prebloom	22	41	31	8	24	.66	65	1.8	.30
Early bloom	18	48	38	10	31	.59	58	1.2	.23
Mid-bloom	16	50	40	11	33	.57	56	1.3	.22
Full bloom	15	52	42	12	35	.55	54	1.3	.20
Alfalfa-Grass mixture—									
average	17	52	36		29	.56	55	1.2	.26
Bromegrass—early	11	68	40	4	33	.57	56	.29	.28
Clover, red									
Early bloom	19				23	.66	64	2.3	.38
Full bloom	15	56	41	10	30	.60	59	1.0	.27
Corn silage—dent	8	51	31		24	.70	70	.27	.20
Corn stover	6	67	39	11	34	.59	58	.38	.42
Orchardgrass—early	15	61	34	5	31	.64	62	.27	.34
Small grain silages—									
Barley—average	10				30	.51	51	.34	.28
Oats—vegetative	13	58			30	.64	62	.47	.33
Sorghum-sudangrass—									
average	9	65	40	5	36	.56	55	.46	.21
Timothy—early	9	61	32	4	28	.60	59	.53	.25

The following example illustrates how ACP is calculated:

Alfalfa-Grass Haylage	DM Basis
CP%	16.5
ADF – N%	.4

Step 1. Calculate CP in ADF from ADF-N

$$\text{CP\% in ADF} = \text{ADF} - \text{N\%} \times 6.25$$
$$2.5\% = .4 \times 6.25$$

Step 2. Determine ADF-CP as percentage of the total CP

$$\underset{\text{\% of total CP}}{\text{ADF} - \text{CP\%},} = \frac{\text{CP\% in ADF}}{\text{CP\%}} \times 100$$

$$15.2\% = \frac{2.5\%}{16.5\%} \times 100$$

Step 3. Calculate ACP%

$$\text{ACP\% of DM} = \frac{\text{CP\%} \times [100 - (\text{ADF} - \text{CP\%} - 12\%)]}{100}$$

$$16.0\% = \frac{16.5\% \times [100 - (15.2\% - 12\%)]}{100}$$

Note: If ADF-CP is 12 percent or less of CP, ACP = CP.

Fiber

The bulky characteristic and components of forage come from fiber. Forage feeding values are negatively associated with fiber since the less digestible portions of plants are contained in the fiber fraction. Fiber contents are used to calculate energy content, digestibility, and potential intake of forages, as well as provide insight into reasons for off-feed, acidosis, and milk fat depressions in cows.

Crude Fiber (CF) is the oldest measure of fiber and refers to the residue of feedstuffs resistant to acid and alkali treatment. Crude fiber increases as plants mature. It doesn't always accurately reflect forage energy content as it tends to underestimate good quality forages and overestimate poor quality forages. Also, CF does not chemically identify the fiberous components in forages. Because of these limitations, new and more accurate methods of quantifying fiber in forages have been developed.

The detergent fiber analysis system separates forages into two parts: cell contents or neutral detergent solubles, which include sugars, starches, proteins, nonprotein nitrogen, fats, and other highly digestible compounds; and, the less digestible components found in the fiber fraction. The fiber factions are contained in the cell walls of plants and provide structural support for upright growth. Figure 1 illustrates these various fractions of plant cells and their chemical components.

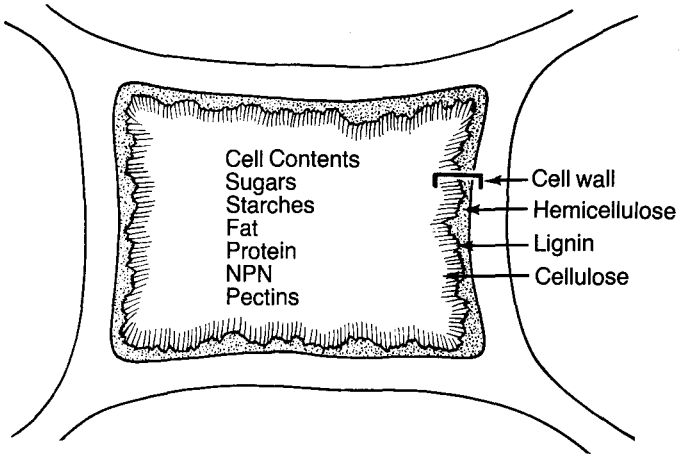

Figure 1. Plant cell fractions and chemical components.

The total fiber content of a forage is contained in the *Neutral Detergent Fiber* (NDF), or cell wall fraction. Chemically, this fraction includes cellulose, hemicellulose, lignin, and heat-damaged protein. Because of these chemical components and their association with bulkiness of feeds, NDF is closely related to feed intake and rumen fill in cows.

The NDF content of various forages is in table 1. Digestibility of NDF in forages ranges from 20 to 80 percent, depending on forage species and stage of maturity. Cell contents, on the other hand, are nearly 100 percent digestible. Cell contents are determined by 100-NDF percent.

The *Acid Detergent Fiber* (ADF) fraction contains cellulose, lignin, and heat-damaged proteins. It is closely related to indigestibility of forages and used in calculating energy content.

Lignin is another component found in cell walls of forages and is measured by either *Acid Detergent Lignin* (ADL) or *Permanganate Lignin* (PML) procedures. Lignin is almost completely indigestible and therefore, as the lignification of forages increases, digestibility decreases.

A list of the fiber fractions along with their chemical components and digestibilities are in table 2. The main factors affecting feeding value of forages relative to fiber are species and date-of-cutting. Grasses are higher in NDF than legumes but lower in lignin. Thus, grasses have lower potential intakes than legumes but contain more digestible cellulose because of less binding from lignin. Early cut, bud, or late vegetative stage legumes are low in fiber, contain less lignin than when mature, and have the highest potential intake of any forages. Therefore, these forages are recommended for high producing dairy cows.

Table 2. Fiber fractions, components, and digestibilities.

Fraction	Components	Digestibility
Cell walls (NDF)	Hemicellulose	20-80%
	Cellulose	50-90%
	Lignin	0-20%
	Heat damaged protein	variable
	Keratin	
ADF	Cellulose	50-90%
	Lignin	0-20%
	Heat damaged protein	variable
ADL	Lignin	0-20%
Cell solubles (100-NDF%)		95-100%
	Starches	
	Fats	
	Soluble proteins	
	Nonprotein nitrogen	
	Sugars	
	Pectins	

Digestible Dry Matter (DDM)

The digestibility of forages can be analyzed either invitro (artificial rumen) or invivo (actual animal digestion trial) or predicted indirectly from fiber. Invitro DDM is often 6 to 10 units above invivo values. Most laboratory reported DDM values are calculated based on invivo values. The national standard formula for alfalfa and alfalfa-grass mixtures DDM (invivo) is:

$$\text{DDM\%} = 88.9 - (.779 \times \text{ADF\%})$$

Total Digestible Nutrients (TDN)

TDN is a measure of energy and is defined as:

TDN% = Digestible CP + Digestible CF + Digestible nitrogen free extract + (Digestible fat × 2.25)

The TDN values shown on forage analysis reports are calculated, primarily from CF or ADF. Estimates of TDN can be made using the following formulas:

Alfalfa or Legume Grass Forages

$$TDN\% = 78.7 - (CF\% \times .8)$$
$$TDN\% = 96.35 - (ADF\% \times 1.15)$$

Corn Silage

$$TDN\% = 72.1 - (CF\% \times .34)$$
$$TDN\% = 87.84 - (ADF\% \times .7)$$

TDN also is equal to invivo DDM

$$TDN\% = DDM\%$$

Net Energy (NE)

The energy contained in feedstuffs is used equally as well for maintenance as for milk production in lactating cows. Therefore, separation of feed energy into amounts used for maintenance or milk production is of little concern. This is not true when considering energy used for maintenance and body weight gain. Feed energy is used less efficiently for depositing new body tissue than for maintaining existing body tissue. For lactating dairy cows, however, only one net energy value, net energy of lactation (NE_L), is needed when balancing rations to meet both maintenance and milk production requirements. NE_L is usually expressed as megacalories (Mcal) per pound or 100 pounds of feed DM.

ADF is the single plant component most highly related to NE_L. As ADF increases, NE_L decreases. The formulas for calculating NE_L from ADF for various forage species are:

Legumes

$$NE_L \text{ (Mcal/lb)} = 1.044 - (ADF\% \times .0123)$$

Grasses

$$NE_L \text{ (Mcal/lb)} = 1.50 - (ADF\% \times .0267)$$

Legume-Grass Mixes

$$NE_L \text{ (Mcal/lb)} = 1.044 - (ADF\% \times .0131)$$

Corn and Small Grain Silages

$$NE_L \text{ (Mcal/lb)} = .3133 \times \left[2.86 - \left(\frac{35.5}{100 - (ADF\% \times 1.67)}\right)\right]$$

or NE_L can be calculated directly from TDN

$$NE_L \text{ (Mcal/lb)} = (TDN\% \times .01114) - .054$$

Dry Matter Intake (DMI)

The amount of forage or feed DM an animal will consume is affected by how fast forages are digested and pass through the intestinal tract. The fiber fraction which appears to be most clearly related to the DMI of forages is NDF. However, the reliability of using NDF to predict total DMI (forage plus grain) is uncertain at this time. Therefore, forage NDF values should only be used to compare potential DMI of forages and not to estimate total ration DMI. The following equation estimates the potential DMI of forage at maintenance level:

$$DMI\ (g/kg\ BW^{.75}) = [96.4 - (.0003 \times CP\%) - (.0482 \times NDF\%) - (.0085 \times NDF\% \times NDF\%)] \times 1.75$$

Relative Feed Value (RFV)

RFV is an index used to rank forages based on their potential DDM and DMI. The formula for calculating RFV is:

$$RFV\% = \frac{(DDM \times DMI)}{100} \times 1.435$$

Standards for RFV as a criteria to grade hay have been proposed by the Hay Marketing Task Force of the American Forage and Grassland Council. The standards for legumes and grasses are listed in table 3. The RFV along with CP should be the criteria on which forages are marketed or fed. High producing dairy cows require forages with RFV's above 118.

Table 3. Forage quality paramaters of legumes and grasses grown in Minnesota.[a]

Stage of Maturity	Quality analyses CP (%)	ADF (%)	NDF (%)	Relative Feed Value[b]
	Legumes			
Prebloom	>19	<31	< 40	<132
Early bloom	17-19	31-35	40-46	118-132
Mid-bloom	13-16	36-41	47-51	102-117
Full bloom	<12	>41	>52	<102
	Grasses			
Pre head	>18	<33	<55	>109
Early head	14-18	33-38	55-60	93-109
Head	8-12	41-39	61-65	80-92
Post head	<8	>42	>66	<80

[a]All values are on a DM basis
[b]Calculated using formulas cited on page 4

Minerals

The total mineral content of feedstuffs is called ash. Forages normally contain 3 to 12 percent ash, DM basis. Organic matter is determined by 100-ash percent.

Minerals can be divided into two groups. Macro are those required by animals in relatively large amounts and include calcium, phosphorus, potassium, magnesium, sulfur, and salt or sodium chloride. Micro or trace minerals are required in small amounts and include iron, iodine, cobalt, copper, manganese, zinc, and selenium.

Ideally, forages should be tested for all macro and micro or trace minerals. Most forage tests only include calcium and phosphorus, however. If reproduction, health, or low milk production problems are occurring, trace mineral analyses on forages may be warranted. The mineral values reported on forage test reports can be used directly in ration formulation.

Dairy Rations and Forage Tests

Visual appraisals, guesses, or book values are inadequate for determining the feeding value of forages. To obtain maximum animal performance at lowest feed costs, animal requirements must be met through testing forages for composition and then nutritionally balancing rations to compliment forage nutrients. Some general considerations regarding dairy rations and forage tests are described below. The suggested nutrient content of dairy rations for animals at different production levels is shown in table 4.

Table 4. Recommended nutrient content of rations for dairy cattle.

Nutrient	Lactating cows					Dry pregnant cows
	Body wt.	Milk (lb/day)				
	<900 1100 1300 >1500	<18 <24 <31 <40	18-29 24-37 31-46 40-57	29-40 37-51 46-64 57-78	>40 >51 >64 >78	
	DM basis					
Energy						
NE_L, Mcal/lb		.64	.69	.73	.78	.61
TDN, %		63	67	71	75	60
Crude protein, %		13	14	15	16	12
Fiber - Current recommendation						
CF, %		17	17	17	17	17
ADF, %		21	21	21	21	21
Fiber - Proposed guidelines*						
NDF, %		45	39	33	28	49
ADF, %		31	28	24	20	24
Calcium, %		.43	.48	.54	.60	.37
Phosphorus, %		.31	.34	.38	.40	.26

*University of Georgia, D.R. Mertens.

Energy

The highest quality forages should be fed to cows in early lactation. Lower quality forages are acceptable for cows in later lactation or non-lactating animals. Forages above 118 in RFV or corn silage are highest in energy content. Although corn silage is probably highest in energy, the moisture content and high NDF may limit its intake. Likewise, grasses have high NDF contents which also limit their intake. Therefore, rations containing two-thirds or more of the forage from alfalfa are suggested for cows in early lactation.

Protein

Forages high in ADF or having a brown, caramelized appearance with a tobacco aroma should be analyzed for heat damage. If ADF-CP values are greater than 12 percent of the total CP, an ACP should be calculated and used for ration balancing.

Legumes will be highest in CP, followed by grasses and then corn silage. This is another reason why alfalfa or legumes are suggested for cows in early lactation where CP requirements are highest.

Fiber

The energy content of a forage is directly related (negatively) to ADF whereas NDF is a good predictor of a forage intake potential. It is suggested that lactating dairy cows have a minimum of 20 percent ADF and 28 percent NDF in the total ration DM to maintain milk fat tests, good rumination, and maximize DMI. However, the source, composition, and physical form or length of fiber can affect this recommendation. Both ADF and NDF should be considered when determining fiber adequacy of dairy rations.

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