TESTING ALFALFA HAY: NEW HAY QUALITY STANDARDS AND TESTING PROCEDURES

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Energy and protein are the most valuable components of alfalfa. Crude protein content of alfalfa can be determined directly in a laboratory, but there is no direct chemical test to determine its energy value. However, the energy value of alfalfa hay is closely related to its fiber content. As the alfalfa plant matures, its fiber content increases and its energy value decreases. Several fiber tests are used in the U.S. to estimate the energy value of alfalfa hay.

Modified crude fiber (MCF)

Research conducted at the University of California in the 1950's established relationships that reliably predict the energy value of alfalfa from its modified crude fiber (MCF) content. MCF differs from crude fiber (CF) because MCF includes the silica (dirt) present in a sample. As crude fiber and dirt in a sample increase, energy and protein contents decrease. The standard CF analysis does not include silica. Therefore, it is not as accurate as MCF in predicting the nutritional value of alfalfa. The equations for predicting the energy value of alfalfa, measured as total digestible nutrients (TDN), or net energy for lactation (NEL), are [all constituents expressed on a 100% dry matter (DM) basis]:

TDN (% of DM)	= 81.07 - .8558 MCF%	(Equation 1)
NEL (Mcal/lb DM)	= .8465 - .0095 MCF%	(Equation 2)
NEL (Mcal/kg DM)	= 1.8662 - .02097 MCF%	(Equation 3)

The above equations give values on a 100% DM basis. Common use of the MCF test in the past has been on a 90% DM basis because most hay is near 90% DM when it is fed regardless of how much moisture it contained when it was packaged. However, it is more convenient to compare nutrient values among various lots of hay, and among various feed ingredients, if they are all expressed on a 100% DM basis. This is particularly true when comparing values of wet feeds, such as silage and haylage, with values of drier feeds, such as hay and grain. If values on other than a 100% DM basis are required, they can be calculated by multiplying the values obtained from Equations 1, 2 and 3 by the desired DM percentage.

Examples: What is the TDN percentage at 90% DM of an alfalfa hay sample with 24% MCF at 100% DM?

TDN (% of DM) = 81.07 - .8558 MCF%
= 81.07 - (.8558) (24)
= 60.5%

TDN% @ 90% = TDN (% of DM) X 90%
= 60.5 X .90
= 54.7%

The MCF test has been used extensively in California for more than 30 years, and has served the industry well. The main disadvantage of MCF is that it is accurate only for pure alfalfa samples. The test is not appropriate for samples that are mixtures of alfalfa and grasses, nor for alfalfa samples that are contaminated with weeds. This is a serious drawback in many areas where alfalfa-grass mixtures are more common than pure stands of alfalfa. However, in western states where pure alfalfa stands are the rule rather than the exception, the MCF test is as accurate as any of the other tests that have been developed more recently.

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Neutral detergent fiber (NDF) and Acid detergent fiber (ADF)

Research conducted by USDA scientists at Beltsville, Maryland, resulted in chemical procedures to identify various plant components using detergents and mixtures of acid and detergent. When a forage sample is ground and mixed with a neutral detergent (sodium lauryl sulfate), the cellular contents (lipids, soluble protein, nonprotein nitrogen, starch, and pectins) go into solution. All of these fractions are highly digestible. The remainder of the sample is called neutral detergent fiber (NDF) and contains the hemicellulose, cellulose, lignin, insoluble protein, and insoluble minerals. NDF consists of the structural components of a plant cell which are bulkier and less digestible than the cell contents that go into solution in neutral detergent. NDF content has been shown to be correlated with voluntary intake of forages by ruminant animals.

If a sample is mixed with acid (1 normal sulfuric acid) and detergent (cetyl trimethyl-ammonium bromide), the hemicellulose of the NDF fraction also goes into solution. The remainder of the sample (cellulose, lignin, insoluble protein, and insoluble minerals) is called acid detergent fiber (ADF). The constituents of ADF are the least digestible portions of plant materials. As was the case for MCF, ADF is inversely related to the digestibility of forages. Popularity of the ADF analysis is increasing relative to MCF because it is an easier and faster test to conduct, is a more discrete and scientifically-based test, and is a more accurate measure of digestibility of alfalfa-grass mixtures and forages other than alfalfa. Furthermore, limited research has shown it to be as accurate as MCF for predicting the energy values of pure alfalfa samples. Equations for predicting the TDN and NEL values of alfalfa grown in the western states, based on limited research conducted to date, are (all constituents expressed on a 100% DM basis):

TDN (% of DM)	= 82.38 - .7515 ADF%	(Equation 4)
NEL (Mcal/lb DM)	= .8611 - .00835 ADF%	(Equation 5)
NEL (Mcal/kg DM)	= 1.8983 - .0184 ADF%	(Equation 6)

Energy prediction equations for forages based on their ADF content are in use in many states. Statistical analysis of alfalfa digestibility data from many areas resulted in the development of a National Equation for prediction of digestible dry matter (DDM) from ADF. The equation is (all constitutents on a 100% DM basis):

DDM (% of DM)	= 88.9 - 779 ADF%	(Equation 7)

The National Equation is useful for comparing the DDM content of alfalfa from various areas. However, it is recommended that equations 1-6 be used to estimate alfalfa energy values because those equations were developed from digestibility trials using alfalfa grown in the western states.

Near infrared reflectance spectroscopy (NIRS)

Research at the USDA experiment station in Beltsville, Maryland, resulted in the development of a machine that measures the reflectance of a band of light shining on a finely ground sample, and correlates the measurements with the composition of the sample as determined in a chemical laboratory. Speed of analysis is the major advantage of NIRS. Chemical analysis of a forage sample may take one or more days to complete, but similar information can be obtained by NIRS in only 10-15 minutes. Accuracy of NIRS analysis is as good as chemical analysis if the NIRS instrument is properly calibrated for the forages being analyzed. Considerable research has been conducted to determine how to obtain the best calibrations. Experience has shown that calibrations must be different for alfalfa grown in the western states than for other parts of the U.S. Differences probably are due to irrigation practices in the west, and the prevalence of alfalfa-grass mixtures outside of the western states. Limited research with alfalfa grown in Californa and Nevada has resulted in improved calibrations for NIRS machines used in the west. Their popularity and use probably will increase markedly in the future because of their speed of analysis and repeatability of test results.

ESTIMATED NUTRIENT CONTENT OF ALFALFA

There are five major classes of nutrients needed by cattle (energy, protein, minerals, vitamins, and water). Energy is most often limiting for milk production, so the energy value of alfalfa deserves the greatest emphasis. High-energy alfalfa also is high in protein, a very important nutrient.

Total digestible nutrients (TDN) and net energy for lactation (NEL) are two of the most common measures of the energy value of feeds. TDN has been used extensively in the past, but NEL has the advantage of greater accuracy when comparing energy values of different types of feeds for dairy cattle. TDN overevaluates forages in comparison with grains and other concentrate feeds. More energy is lost as heat from forages, leaving less of the digestible energy available for productive purposes such as growth and milk production. This heat loss, plus the losses of energy in the expelled gases and urine, are subtracted from digestible energy when determining the NEL value of a feed.

Although NEL is more accurate when comparing the energy values of different types of feeds, and for ration balancing for dairy cattle, there is little difference in the accuracy of NEL and TDN when comparing relative energy values of different lots of alfalfa hay. Thus both the NEL and TDN values of alfalfa predicted from either MCF or ADF are included in Tables 1 and 2 as both are used extensively in the field. Digestible dry matter (DDM) predicted from ADF also is included in Table 4 for use in comparing values nationwide.

LABORATORY REPORTS

Laboratory test data for alfalfa samples are reported in various formats by different laboratories, often causing confusion among hay growers, purchasers, and others using the test data. Some laboratories report results on a 100% DM basis, some at 90% DM, and some on an "as received" DM basis. For the sake of utility and clarity, laboratories should report data on all three of the above mentioned DM bases, as shown in Figure 1.

Values for TDN, NEL, and DDM at 100% DM can be calculated for Equations 4, 5 and 7, or estimated from values in Table 1. In Figure 2, the sample contained 30% ADF. From Table 1, a sample with 30% ADF contains 59.8% TDN and .611 Mcal NEL/lb DM. To convert to "as received" and 90% DM basis, multiply the values by the corresponding DM percentages, in this case 87% and 90%. Thus, the sample with 30% ADF has 59.8% TDN and .611 Mcal NEL/lb at 100% DM, 53.9% TDN and .550 Mcal NEL/lb at 90% DM, and 52.1% TDN and .531 Mcal NEL/lb at 87% DM.

The bottom portion of the suggested form contains boxes to indicate the relative nutritional value of the sample. Four categories are listed (Premium, Good, Fair, and Low) which correspond to ratings listed in the California Hay Market News published by the California Department of Food and Agriculture, and in the Nevada Hay Market News published by the University of Nevada. A sample must contain not more than 29% ADF to qualify for the "Premium" category, 29.1-32% ADF for "Good", 32.1-37% ADF for "Fair", and samples with more than 37% ADF are in the "Low" category. The sample in Figure 1 contains 30% ADF at 100% DM so it is in the "Good" category.

For laboratories using the MCF test procedure, values for TDN and NEL can be calculated from Equations 1 and 2, or estimated from values in Table 2 similar to the procedure described above for the ADF procedure. MCF percentages for the four Hay Quality Rating categories also are shown in Figure 1.

Table 1. Net Energy for Lactation (NEL), Total Digestible Nutrients (TDN) and Digestible Dry Matter (DDM) of alfalfa estimated from its Acid Detergent Fiber (ADF) content.

	-------(100% DM basis)-		
ADF	TDN	NEL	DDM
	(%)	(Mcal/lb)	(%)
20	67.4	.694	73.3
21	66.6	.686	72.5
22	65.8	.677	71.8
23	65.1	.669	71.0
24	64.3	.661	70.2
25	63.6	.652	69.4
26	62.8	.644	68.6
27	62.1	.636	67.9
28	61.3	.627	67.1
29	60.6	.619	66.3
30	59.8	.611	65.5
31	59.1	.602	64.8
32	58.3	.594	64.0
33	57.6	.585	63.2
34	56.8	.577	62.4
35	56.1	.569	61.6
36	55.3	.560	60.9
37	54.6	.552	60.1
38	53.8	.544	59.3
39	53.1	.535	58.5
40	52.3	.527	57.7
41	51.6	.519	57.0
42	50.8	.510	56.2
43	50.1	.502	55.4
44	49.3	.494	54.6
45	48.6	.485	53.8

Table 2. Net Energy for Lactation (NEL) and Total Digestible Nutrients (TDN) of alfalfa estimated from its Modified Crude Fiber (MCF) content.

MCF (%)	TDN (%)	NEL (Mcal/lb)
	(100% DM basis)	
16	67.4	.694
17	66.5	.685
18	65.7	.676
19	64.8	.666
20	64.0	.656
21	63.1	.647
22	62.2	.638
23	61.4	.628
24	60.5	.618
25	59.7	.609
26	58.8	.600
27	58.0	.590
28	57.1	.580
29	56.2	.571
30	55.4	.562
31	54.5	.552
32	53.7	.542
33	52.8	.533
34	52.0	.524
35	51.1	.514
36	50.3	.504
37	49.4	.495
38	48.5	.486

Laboratory Analyses:

	Dry Matter Basis		
	As Received	90% DM	100% DM
Dry matter (DM), %	87.0	90.0	100.0
Acid detergent fiber (ADF), %	26.1	27.0	30.0
Modified crude fiber (MCF), %	21.6	22.3	24.8
Crude protein (CP), %	17.4	18.0	20.0

Estimated Energy Values (Calculated From ADF or MCF)

Total Digestible Nutrients (TDN), %	52.1	53.9	59.8
Net Energy for Lactation (NEL), Mcal/lb	.531	.550	.611
Digestible Dry Matter (DDM), %	57.0	59.0	65.5

Hay Quality Rating for This Sample:
(ADF and MCF values on a 100% DM basis)

☐	Premium	(29% ADF or less)	or	(24% MCF or less)
☒	Good	(29.1-32% ADF)	or	(24.1-27% MCF)
☐	Fair	(32.1-37% ADF)	or	(27.1-31% MCF)
☐	Low	(Above 37% ADF)	or	(Above 31% MCF)

Figure Suggested laboratory form for reporting chemical and nutrient values of alfalfa.