ACCURACY OF THE MODIFIED CRUDE FIBER AND ACID DETERGENT FIBER TESTS TO PREDICT TDN OF ALFALFA HAY

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The chemical test used in California to estimate the total digestible nutrient (TDN) content of alfalfa hay resulted from an extensive research project conducted at the University of California, Davis in the 1950's. During that time, 198 digestion trials were conducted using 43 different lots of alfalfa hay from nine counties in California, the counties being Shasta, Yolo, Monterey, Stanislaus, Fresno, Kings, Kern, Los Angeles, and Imperial. Thus, the hay was from both the northern and southern parts of the state, from high elevation to below sea level, and from the coastal area to the central valley. Data collected during the digestion trials were used to calculate the actual TDN of the hays when they were fed to test animals. Samples of each of the hay lots also were analyzed for their chemical constituents in a laboratory. Several of the chemical constituents were found to be correlated with the TDN content of the test hays. The four constituents found to have the closest relationship to TDN were crude protein (CP), lignin (Lig), crude fiber (CF), and a test developed at UC Davis called modified crude fiber (MCF). The equations developed to predict TDN from each of the above chemical constituents and their correlation coefficients (r) are shown in Table 1.

The chemical constituent of alfalfa hay found to have the highest correlation with its TDN content was MCF ($r = -.89$). However, none of the parameters tested were found to have a perfect correlation with TDN, which would be an $r = \pm 1$. Statistical analysis of the data showed that TDN could be estimated with an accuracy of $\pm 1\%$ TDN if 19 core samples from a lot of baled alfalfa hay were composited and analyzed by the MCF test. If more than 19 core samples were analyzed, the accuracy would be better, and if less were taken, the accuracy would be less. Therefore, if a laboratory report of a sample of hay composited from 19 core samples shows a TDN of 53% based on its MCF content, the actual TDN of that hay could be anywhere between 52-54% TDN.

In recent years, a new fiber test has been developed by USDA researchers that was unknown in the 1950's when the California MCF test was developed. It is based on treating hay samples with detergents and acids to separate the digestible and indigestible constituents of feed ingredients. The test, known as acid detergent fiber (ADF) has been shown, in cooperative experiments at UC Davis and the University of Nevada, Reno, to be as good as MCF in estimating the TDN of alfalfa hay, as shown in Table 1, and better than MCF for grasses and other forages. The ADF test is used for forage testing in most other states because it is faster and easier to run in a laboratory. Also, it is more accurate than MCF on alfalfa-grass mixtures which are common in most areas except the western states. The ADF test also has been adapted to near infrared reflectance (NIR) machines which are becoming more popular for forage testing because of their speed and potential accuracy if properly calibrated.

National Equation

Recent cooperative research on alfalfa-grass hays in several eastern and mid-western states resulted in the suggestion of a National Equation to predict the digestible dry matter (DDM) of alfalfa and alfalfa-grass mixtures based on their ADF content. The equation is: DDM% = 88.9 -.779 ADF%, with $r = -.88$. To convert DDM% to TDN%, the equation is: TDN% = .9707 DDM% -.3856. If net energy for lactation (NE_l) values are desired, they can be calculated by the equation: NE_l (Mcal/lb) = .01111 TDN% -.05443.

It would be desirable to have one equation and one method for testing alfalfa nationwide because much hay is exported across state borders for feeding in areas other than where it is produced. The wide variety of tests currently used in many states leads to confusion and actual misrepresentation of alfalfa hay quality in some cases. A single nationwide system would alleviate these problems and result in more orderly marketing of hay based on its nutritional value. Unfortunately, the current National Equation appears to over-evaluate alfalfa grown in California and Nevada. This is illustrated in Table 2 in which the actual TDN values of nine lots of alfalfa hay produced in various areas of California

and Nevada, as determined in digestion trials at UC Davis and the University of Nevada, were compared with TDN values estimated by the California MCF test, the California-Nevada ADF test, and the National Equation.

From the digestion trials, the nine lots of hay had an average of 56.5% TDN (Table 2). The average TDN values estimated from the MCF equation, the California-Nevada ADF equation, and the National Equation were 56.7, 56.5, and 60.7% TDN, respectively. Differences from the actual TDN were 0.2%, 0, and 4.2% for the MCF, ADF, and National Equations, respectively. It is the opinion of this author that the difference of 4.2% calculated by the National Equation is too large to accept it as a substitute for the current MCF test. However, it appears that the California-Nevada ADF equation is as accurate as the MCF equation in estimating the TDN of alfalfa hay, at least for the nine lots of California and Nevada hay used in these experiments.

Suggested Testing and Reporting Procedure

Recognizing the importance of working toward an alfalfa testing system that is accurate and can be used nationally, the following is proposed as an interim compromise procedure. It incorporates the National Equation for purposes of comparing the relative nutritional value of alfalfa grown in all regions of the nation, and retains the accuracy of the current MCF test, and/or the new California-Nevada ADF testing procedure for predicting the TDN and NE_1 of alfalfa hay.

A sample of alfalfa hay should be analyzed for its dry matter content and either its MCF or ADF content. If protein content of the sample is desired, it should be analyzed for crude protein using the Kjeldahl method. Predicting protein content from fiber fractions is not recommended because serious errors can result.

If ADF is determined, the DDM of the sample can be estimated by the National Equation: DDM% = 88.9 -.779 ADF%. Using the equations in Table 1, the TDN content of the sample on a 100% dry matter basis can be estimated from either its MCF or ADF content. Suggested formats for laboratory report forms incorporating the above information are shown in Figures 1 and 2. For ease of use, it is suggested that information on the lab reports be listed in three ways: 1) as received moisture basis; 2) 90% dry matter basis; and 3) 100% dry matter basis. The MCF and TDN values used in California for the last 30 years have been reported on a 90% dry matter basis. Although values on a 100% DM basis are easier to use for ration formulation, the historical use of values at 90% DM has made them familiar to growers and dairymen alike. Retaining them on the report form will maintain a link with the current reporting procedure for comparison purposes. It is suggested that the Hay Quality Rating be retained on a 90% DM basis to correspond with the quality grades currently described in the California Hay Market News reports. It is important to list the dry matter percentage of the hay on an "as received" basis because it is one of the criteria used to establish the dollar value of the hay.

The proposed testing procedure and laboratory report form shown in Figures 1 and 2 have the following advantages:

1. They incorporate the National Equation for estimating DDM to compare the relative nutritional value of alfalfa hay grown in all areas of the nation if acid detergent fiber is determined.

   They utilize either the MCF or CA-NV ADF equations to estimate the TDN and NE_1 energy values of the hay, thus retaining the accuracy of current testing methods in California.

3. The report form can be used for data generated by conventional wet chemistry techniques or by NIR machines.

4. The familiarity of values reported at 90% DM is retained along with the addition of values at 100% DM for ease of use in ration balancing.

Table 1. Equations to estimate total digestible nutrients (TDN) from various chemical constituents of alfalfa hay (100% Dry Matter Basis).

Constituent	Equation	(r)
Crude protein (CP)	TDN% = 33.33 + 1.142 CP%	.80
Lignin (LIG)	TDN% = 79.1 - 2.67 LIG%	-.84
Crude fiber (CF)	TDN% = 78.7 - .8027 CF%	-.87
Modified crude fiber (MCF)	TDN% = 81.07 - .8558 MCF%	-.89
Acid detergent fiber (ADF)	TDN% = 78.2 - .657 ADF%	-.89

Table 2. Comparison of TDN values of alfalfa hay determined in digestion trials and by three prediction equations.

Source of Hay		Digestion Trials	CA MCF	CA-NV ADF	National Equation
			(% TDN at 100% DM)		
Davis, CA	1	56.2	56.6	56.3	60.4
	2	54.8	52.6	53.1	56.8
Lassen, CA	1	61.0	60.8	59.8	64.5
	2	60.0	59.8	59.0	63.6
Fallon, NV	1	57.2	58.2	58.1	62.5
	2	53.6	54.4	54.1	57.9
Imperial, CA	1	55.4	57.4	57.0	61.3
	2	55.5	54.9	55.3	59.3
	3	54.4	55.8	55.7	59.8
Mean		56.5	56.7	56.5	60.7
Difference from digestion trials			0.2	0	4.2

Figure 1. Proposed laboratory reporting procedure for the nutritional value of alfalfa hay if acid detergent fiber is determined.

Lab Analyses:	As Received	90% DM	100% DM
DM (%)	87	-----	-----
ADF (%)	27.0	27.9	31.0
(OR)			
MCF (%)	----	-----	-----
CP (%)	17.4	18.0	20.0
Estimated Energy Values:			
(from ADF or MCF)			
DDM (%)	56.4	58.3	64.8
TDN (%)	50.3	52.0	57.8
NE_l (Mcal/lb)	.51	.53	.59

Hay Quality Rating For This Sample:

/___/ Premium (Above 54% TDN)

/_X_/ Good (52-54% TDN) > 90% DM Basis

/___/ Fair (49-51% TDN)

/___/ Low (Below 49% TDN)

Figure 2. Proposed laboratory reporting procedure for the nutritional value of alfalfa hay if modified crude fiber is determined.

Lab Analyses:	As Received	90% DM	100% DM
DM (%)	87		
ADF (%)	----		
(OR)			
MCF (%)	23.7	24.5	27.2
CP (%)	17.4	18.0	20.0
Estimated Energy Values:			
(from ADF or MCF)			
DDM (%)	----	----	----
TDN (%)	50.3	52.0	57.8
NE_l (Mcal/lb)	.51	.53	.59

Hay Quality Rating For This Sample:

/___/ Premium (Above 54% TDN)

/_X_/ Good (52-54% TDN) > 90% DM Basis

/___/ Fair (49-51% TDN)

/___/ Low (Below 49% TDN)