# Neutral Detergent Fiber (NDF) and its Role in Alfalfa Analysis

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**ABSTRACT**

The key chemical analysis used to estimate the energy value of alfalfa hay for trading purposes, ADF (acid detergent fiber), has been supplanted by NDF (neutral detergent fiber) as the key chemical analysis used by nutritionists to evaluate the fibrosity and energy value of alfalfa hay for nutritional purposes. It is important that the alfalfa hay trading industry abandon ADF, as it will generally be considered obsolete as an index of hay fibrosity within a few years. Suggestions to move to the RFV (relative feed value) system cannot be supported from an objective evaluation of its strengths and weaknesses. The best choice for the California hay trading industry is to move from ADF to NDF as the key chemical analysis used to estimate the energy value of alfalfa hay for trading purposes. This recommendation is supported by the observations that NDF is widely used by dairy cattle nutritionists, NDF accurately predicts the energy (TDN) value of alfalfa hay, and use of NDF will allow future improvements in biological assays to be added to the TDN prediction equation with only minor changes, and there need be no change in TDN as the base term used to describe the energy value of alfalfa hay. It is important that the chemical predictors of the nutritional value of alfalfa hay for trading and nutritional purposes not be allowed to diverge.

Key Words: alfalfa hay, fiber, NDF, ADF, RFV.

## INTRODUCTION

Alfalfa hay continues to be an important forage for dairy cattle in California. It is prized by dairy nutritionists and dairy ranchers for its slowly rumen degraded protein, rapidly rumen fermented non-structural carbohydrates, as well as its high energy value for lactating dairy cows. This latter characteristic is a result of its relatively, for a forage, low levels of structural carbohydrate (i.e., neutral detergent fiber or NDF) that is relatively, for a forage fiber, rapid degraded by microbes in the rumen of dairy cows and other ruminants. As a complete forage nutritional package, it is not really possible to top a high quality alfalfa hay as the sole forage for lactating dairy cows.

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However, when it comes to setting a value for alfalfa hay in California, its energy level seems to be the key characteristic, whether that value is fiscal, as set between the grower and the dairy rancher, or nutritional, as set by the nutrition professional. Yet it is not possible to chemically analyze a sample of alfalfa hay to determine its energy value for dairy cows, as energy is not an analyzable nutritional component. This creates the apparent illogic of fixing the fiscal and nutritional value of alfalfa hay upon a characteristic that cannot be analytically determined. Such a pickle.

But the energy value of alfalfa hay is important. Alfalfa hays with low energy values, regardless of their analyzed nutritional values, are immediately apparent on commercial dairies. The cows talk and the low energy alfalfa walks. Alas, if the cows have spoken, then the dairy producer has already lost milk production and revenue. So the objective is to predict the response of the cows to individual lots of alfalfa hay so that poor quality (i.e., low energy) alfalfa hay is avoided and not included in the ration.

This article discusses fiber, and its components, in the context of the method that is currently used in California to estimate the energy value of alfalfa hay, as well as options under consideration for the future.

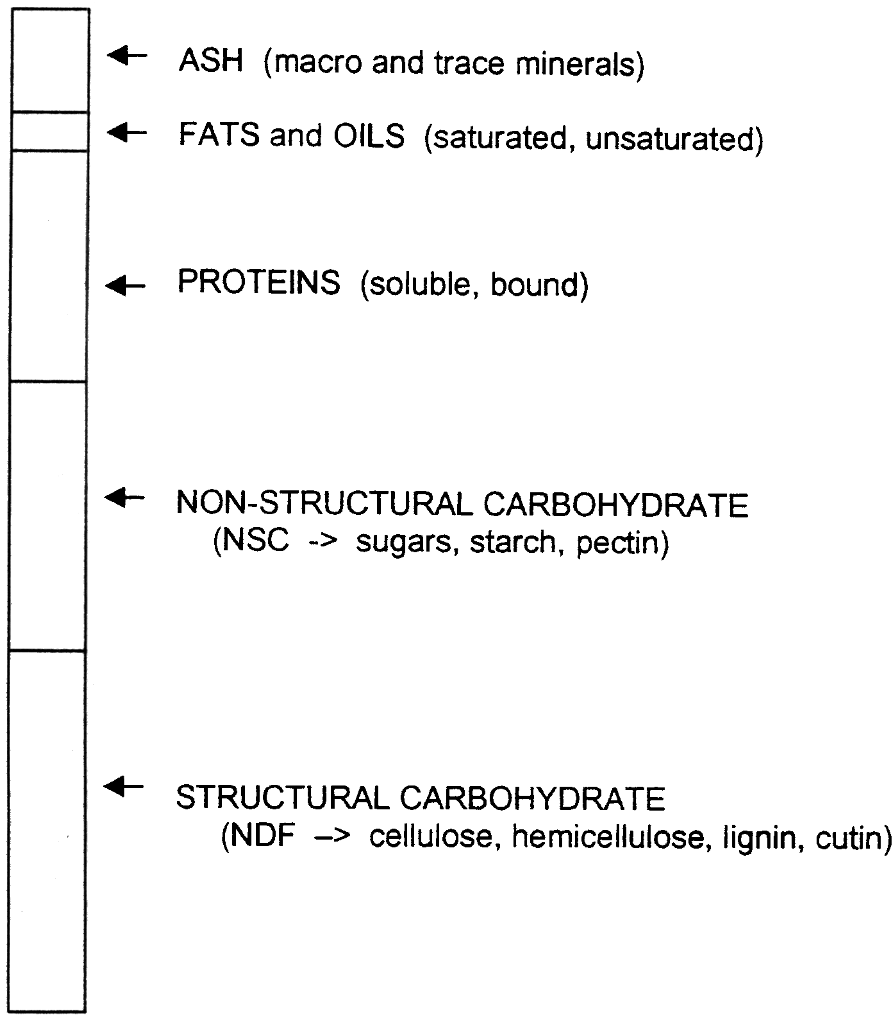
## LABORATORY ANALYSES OF ALFALFA HAY

There are a number of chemical components of alfalfa hay that can be determined by currently available laboratory techniques. Outlined in Figure 1, these allow the alfalfa hay to be divided into its ash (i.e., mineral) component (9 to 13% of hay dry matter (DM)), fat (2 to 3% of DM), protein (15 to 25% of DM), non-structural carbohydrate such as sugars, pectins and starches (20 to 35% of DM), and structural carbohydrates (30 to 50% of DM). Ash, protein, fat and structural carbohydrate (usually defined as fiber insoluble in a solution of boiling detergent at a neutral pH, or neutral detergent fiber (NDF)), are generally assayed directly, while the level of non-structural carbohydrate (NSC) is calculated by difference. Energetically, ash has no value while fat, NSC and proteins are generally almost fully digestible somewhere in the digestive tract. Thus the energy value of the hay, exclusive of the NDF, can be calculated with some accuracy. However it is the NDF portion of the hay, due to its relatively high contribution to the overall weight of the hay and its variable digestibility, that makes it a key variable in estimating the energy value of alfalfa hay.

NDF is made up of four main chemical components. Quantitatively the largest, cellulose and hemicellulose are potentially digestible but, due to their complex chemical structures, resist the attack of digesting microorganisms in the rumen of cows. They are essentially indigestible once they pass out of the rumen. The other main components of NDF are lignin and cutin, which are virtually indigestible in both the rumen and lower intestines. In addition, both inhibit digestion of the underlying and/or associated cellulose or hemicellulose either by physical or chemical shielding. So in a nutshell, as the lignin and cutin levels of alfalfa hay increase, the digestibility of its fiber will decrease.

ADF is basically NDF without the hemicellulose, which can be removed by boiling the hay (or NDF) in a detergent solution at an acid pH. Thus ADF only contains cellulose, lignin and cutin. Students of history may be interested to know that ADF was originally developed as a preparatory step for lignin analysis, and was never intended to be used as a descriptor of the fiber level of feedstuffs.

Figure 1. Commonly Analyzed Components of Alfalfa Hay




So if it is possible to chemically determine all of these fiber components, why is there no assay for the energy level of alfalfa hay (i.e., TDN or total digestible nutrients)? And indeed this is true: there is no TDN assay, as TDN is not a chemical component of alfalfa hay. In fact, TDN describes the ability of the animal to digest the nutrients in alfalfa hay and convert those nutrients to work (i.e., energy). And it is the amount of work (i.e., energy), that the hay will support that defines the energy value of the hay to the animal as no more energy can come out of the animal in milk, meat and heat than is digested by the feeds that the animal consumes. Herein lies the conundrum. We value alfalfa hay for its ability to support a high amount of work, yet we must estimate that ability to support work based upon a set of chemical analyses that do not, and in fact can not, be expected to make that estimate with accuracy or precision.

## PREDICTING THE ENERGY VALUE OF ALFALFA HAY

So how do we, and how could we, and how should we, estimate the energy value of alfalfa hay to both maximize the accuracy and precision of the estimate, while minimizing the cost and time required to do so.

### How We Do It Now

A current method to predict the TDN value of alfalfa hay is based upon a publication of Dr.'s Don Bath and Vern Marble of UC Davis (Testing Alfalfa for its Feeding Value, Leaflet 21457 – WREP 109, 1989; available through any UCCE Office). Bath and Marble noted, as had others before them, that because ADF contained a high proportion of the indigestible fiber components lignin and cutin, that there was a good relationship between the ADF level of a hay and its TDN value. Combined with the speed and low cost of the ADF assay, Bath and Marble felt that ADF was an excellent assay to choose as a predictor of the TDN value of alfalfa hay. In their pamphlet, the best ADF based equation to predict the TDN value of alfalfa hay was suggested to be:

TDN (% of hay DM) = 82.38 – .7515 x ADF %)

This equation, referred to as the 'Western States Equation', has been adopted by virtually all California hay testing laboratories, and has served the industry well over the years as a quick, inexpensive, precise and robust method to predict the TDN value of alfalfa hays.

However there are problems. It is not possible to validate this equation biologically and it was based on hays grown in the central valley of California in the 1980's, making the applicability of this equation to currently grown hays, as well as hays grown in other areas and imported into California, unknown. In addition, the ADF assay, with its dependence upon acidic reagents, is a health and environmental problem in commercial hay testing laboratories. The results of the ADF assay are also highly dependent upon the actual laboratory procedure used to determine it (i.e., the ADF level of a hay is defined by the specific laboratory, and method, that was utilized). Finally, ADF is being abandoned by dairy cattle nutritionists in favor of NDF, a fiber measurement that estimates total structural fiber and so better predicts animal the response to mixed rations provided to groups of cows. As crude fiber (CF) faded out between 1970 and 1990, so ADF is now fading out and will be considered obsolete in most of the developed world, for purposes other than as its originally defined role as a preparatory step for lignin analysis, within a few years.

**How We Could Do It**

Many areas of the US have moved to the use of RFV (Relative Feed Value) as the key determinant of the feeding value of forages in general, including alfalfa hay. Is this the way to go?

RFV is calculated from both the ADF and NDF contents of a feedstuff as:

RFV (units) = (88.9 – (.779 x ADF%)) x (120/NDF%/1.29)

Unlike the Bath and Marble equation, which is only valid for alfalfa hays grown in the central valley, this equation is purported to be valid for any forage grown anywhere, since it incorporates the variable ratios of NDF/ADF that exist among forages. However within alfalfa hay the value of using both NDF and ADF as predictors are nebulous, as Putnam (California Hay Symposium, 1998; page 149) showed that there was a very high linear correlation between NDF and ADF in alfalfa hay (Figure 2). Indeed Putnam also

Figure 2. NDF (%) vs. ADF (%).

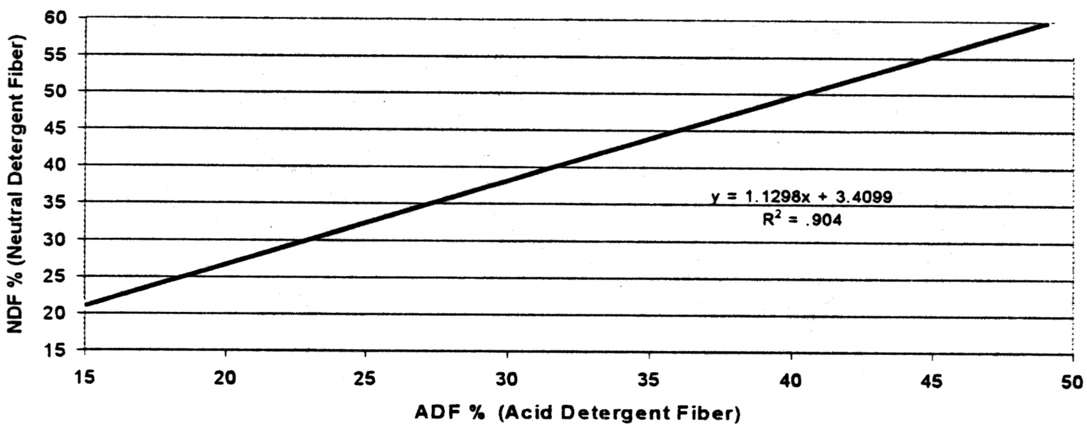
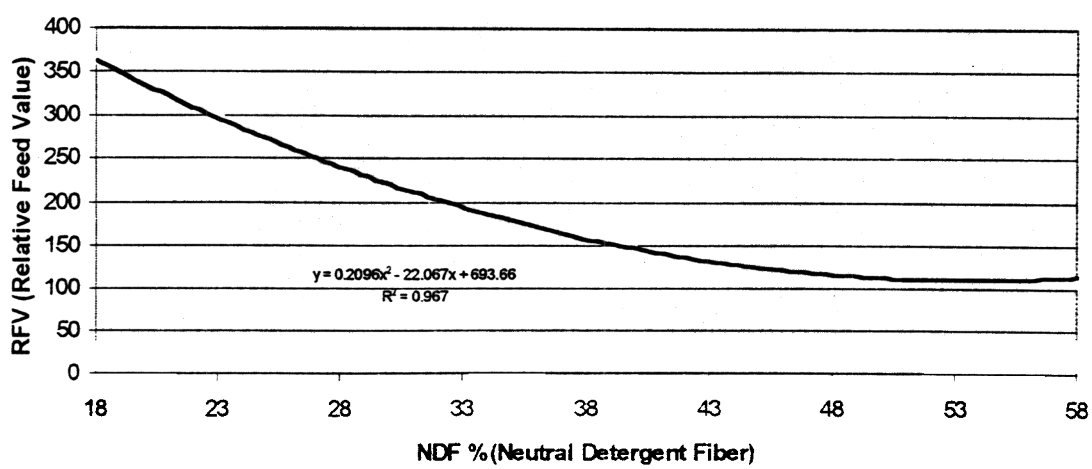



Figure 3. RFV (units) vs. NDF (%).



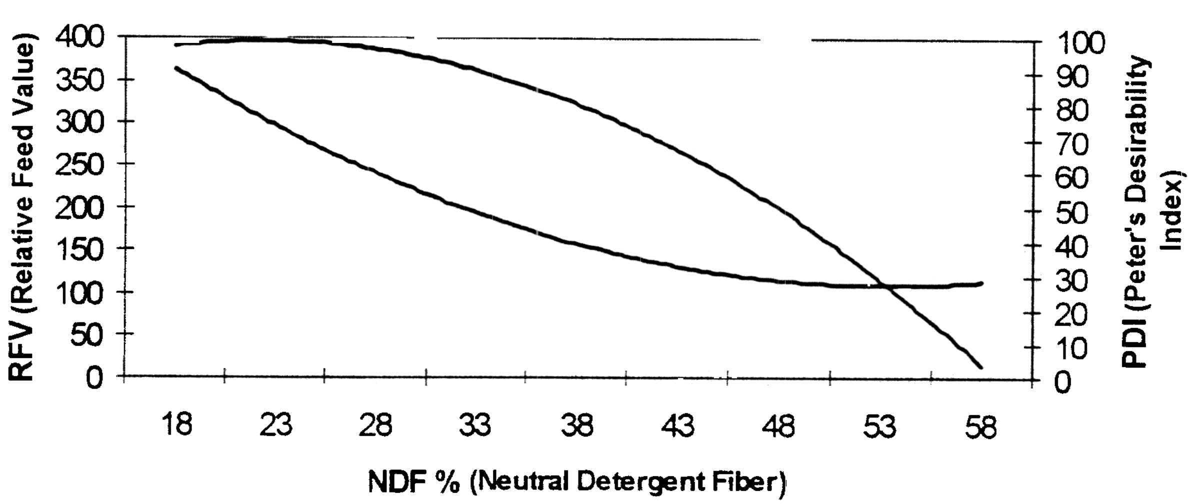
demonstrated (California Hay Symposium, 1998; page 149) that the relationship between the NDF level of alfalfa hay and the calculated RFV value (Figure 3) was virtually perfect (i.e., in alfalfa hay the RFV is synonymous with the NDF level). In other words, armed with either ADF or NDF or RFV of an alfalfa hay, it is possible to estimate either of the other two with a high degree of accuracy. Are we chasing our tails here?

Key advantages of the RFV system are that it reflects the feeding value of any forage, and that it is simple to understand (i.e., the evaluation is in units relative to 100). However the former is not relevant within alfalfa hay and the latter begets reality.

On the negative side of the ledger there are several downsides of RFV as the measure to value alfalfa hay. The first, and most obvious, is that that animals do not have nutritional requirements for RFV units. This means that nutritionists must convert the RFV value to an energy value by re-calculation through the fiber levels. Thus RFV is not a feed value.

It is also clear that RFV is not relative, at least if relative refers to the economic value (i.e., sale price) of the hay. Close examination of Figure 3 indicates that the RFV system predicts that the value of alfalfa hay would increase at an increasing rate as the fiber (NDF or ADF) value declines. In other words, as the NDF value rises above about 40% of DM, equivalent to an ADF of about 32% of DM, the economic value of the hay would become relatively stable. This is not consistent with reality where the actual relationship between fiscal value and the fiber level of the hay is the mirror image of the RFV value (Figure 4). As depicted, Peter's Desirability Index (PDI) suggests that hay value would rise sharply as the fiber level falls from a high value but then stabilizes and may even decrease slightly at extremely low fiber values (as options for the use of this hay decline).

Figure 4. RFV (units, lower) and PDI (units, upper) vs. NDF (%).



Thus since RFV is virtually perfectly correlated to NDF within alfalfa hay, does not describe the nutritional value of the hay for dairy cows, and is neither relative nor a feed value, there seems little reason to adopt it, and several to avoid its adoption, by the California alfalfa industry.

## How We Should Do It Now

Dairy cattle nutritionists are increasingly moving to NDF as the best descriptor of the overall fibrosity of all feedstuffs fed to dairy cattle, as it can be used to predict the potential intake of mixed rations. In addition, nutritionists value NDF as a nutrient since it stimulates chewing and cud chewing in the cow as well as acting as a rumen buffer. The NDF procedure uses fewer dangerous chemicals than does the ADF procedure and so is less of a health and safely issue, as well as an environmental problem, in hay testing laboratories.

So, is it possible to use NDF as the predictor of the energy value of alfalfa hay in place of ADF, and not lose accuracy or precision? Putnam (1998; Figure 3) has shown that there is a very high relationship between the NDF and ADF level of alfalfa hay. Combining the predictive equation of Bath and Marble, noted above, and that of Putnam (Figure 3) it is possible to predict TDN from NDF as:

$$\text{TDN (\% of hay DM)} = 82.38 - .7515 \times ((\text{NDF\%} - 3.41)/1.1298))$$

This equation uses the strength of the original Bath and Marble equation, and the strong correlation of NDF and ADF in alfalfa hay, shown by Putnam (1998), to create a prediction equation that avoids the use of ADF, an assay not needed by dairy cattle nutritionists, in predicting the TDN value of alfalfa hay. Thus a single hay assay, NDF, can meet the needs of hay growers, dairy ranchers and dairy nutritionists.

## How We Might Improve It Later

A shift from ADF to NDF as the predictor of TDN, which will remain the base energy value, also allows future advances in biological understanding, and improvements in analytical methods, to more easily be added to the TDN prediction equation.

Thus is will be possible to improve the accuracy, and perhaps the precision, of energy estimates of alfalfa hay by using equations that include other analyzed components of alfalfa, such as indigestible protein, ash and fat. It may be some time before these nutritional components are used for calculations that value alfalfa hay for trade, but with advances in analytical methods it seems likely to be only a matter of time before it occurs. However it is clear that these expanded equations are increasingly being used for estimating the nutritional value of alfalfa hay for feeding purposes by dairy cattle nutritionists.

Another development that appears certain to find increasing use on the nutritional evaluation side of the hay business is the use of biological assays by commercial laboratories to directly determine the digestion of NDF in the animal. This approach is currently being used to a limited extent by nutritionists to more accurately estimate the energy value of alfalfa hay. These biological estimates of NDF digestion are available from some commercial laboratories now. However due to problems of expense and time, it seems unlikely that methods will find application in the hay trade in the near future.

## CONCLUSIONS

Alfalfa hay continues to be a premier forage for dairy cows in California. However the ADF analysis currently used to estimate its energy value for hay trading purposes is being supplanted by NDF among dairy cattle nutritionists. ADF will fade from general use over the next five years as crude fiber (CF) faded from use before it. In order to keep the hay trading analysis base consistent with the nutritional use of alfalfa hay, it is important that the California alfalfa industry abandon ADF as its key nutritional evaluator in the near future. Arguments for use of RFV (Relative Feed Value) are spurious, as RFV is neither relative nor a feed value within alfalfa hay. The best choice as a replacement for ADF is NDF, as it is widely used by dairy cattle nutritionists, accurately predicts the energy (TDN) value of alfalfa hay, and will allow future improvements in biological assays to be added to it with only minor changes to the base TDN prediction equation, and no change in TDN as the term used to describe the energy value of alfalfa hay.

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