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What's all the Fuss About NDF ?

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Hay quality is a term that is often used, but seldom defined, by both hay growers and hay buyers. This is because, as beauty is defined by the beholder, hay quality is defined by the purpose for which the hay is to be used. For hay growers and buyers, quality is the single most important hay descriptor since it allows the value (i.e., the price) of the hay to be set for purposes of trading. In a nutshell, as hay quality goes up, so does the price. Thus hay growers and buyers ask animal nutritionists the very reasonable question: "What exactly is hay quality?", and then go on to ask forage specialists the very reasonable follow-up question: "How exactly do I increase and measure hay quality?". Simple questions to be sure, but answers can be very complex.

What is Hay Quality ?

The quality of a lot of hay for dairy cattle encompasses a number of characteristics. However the three key ones are its energy value, intake potential by cows, and its ability to stimulate normal rumen function and cud-chewing.

Dairy nutritionists are increasingly using neutral detergent fiber (NDF – which estimates the total structural material in hay) in ration formulation because it better predicts the intake potential of mixed rations fed to dairy cows. The reason for this is that NDF, in general, is the slowest digesting portion of all feedstuffs. Until it clears the rumen, either by digestion in it or passage to the small intestine, it has a filling effect which inhibits further feed intake. This is particularly the case if the NDF level of the diet is too high and, in general, dairy cows will eat no more than 1.4% of their body weight as NDF each day, which is about 18 lbs of NDF for an average cow. Thus the best estimator of hay intake potential is its level of total structural fiber (i.e., its NDF level).

High producing dairy cows producing over 100 lbs of milk per day are often limited by their ability to consume sufficient energy in the diet to meet their energy requirements for milk production and maintenance of body functions. Phrased differently, high producing dairy cows have a limited capacity to consume energy relative to their total energy needs. This being the case, it may seem logical to simply feed these cows high levels of energy-rich grains and fats to eliminate energy as a limitation to milk production.

However, these same cows depend upon a balanced fermentation process in their rumens to digest feedstuffs that have been consumed. To keep rumen fermentation balanced, high producing dairy cows require a source of structural fiber to give integrity to the rumen contents, stimulate cud-chewing, and produce fermentation end-products that can be used by the cows' tissues to produce milk fat and protein. Thus for high producing dairy cows, a high quality hay combines a relatively high level of energy and a relatively low level of structural fiber. In contrast, the production of lower producing dairy cows is generally not limited by their ability to consume energy (i.e., these cows have a high capacity to consume energy relative to their energy needs). Thus, for lower producing dairy cows, a high quality hay combines a moderate level of energy and a moderate level of structural fiber.

There are a number of chemical analyses that can be performed on hay to predict its nutrient composition. However of all of the chemical analyses that are available, currently the one analysis that best predicts hay quality is NDF, since NDF is related to the intake potential of the hay, the rumination and cud-chewing stimulus of the hay, as well as the energy value of the hay. Taken together, these three characteristics **define** the key aspects of hay quality.

Why Can't the Energy Value of Hay be Assayed Directly ?

The common energy term used in California is TDN. Short for total digestible nutrients, TDN estimates the proportion of the hay that can be digested by dairy cattle. TDN is a very old concept that was first developed in the late 1800's. It has changed over time, but is now generally accepted to represent the sum of the digestible protein, digestible fat (multiplied by 2.25), digestible non-structural carbohydrate and digestible structural fiber (i.e., NDF), all corrected for a metabolic cost of digestion. The reason that the TDN value of hay cannot be chemically analyzed is that while the levels of protein, fat, non-structural carbohydrate and NDF can be assayed in a hay sample, their actual digestibility in the cow to which the hay is fed cannot. For this reason, it is only possible to **predict** the TDN level of the hay. The objective of research at UC Davis in the 1960's and 1970's by Don Bath and Vern Marble was to identify a fast and inexpensive hay assay that was well related to its TDN content.

How is Hay Quality Predicted in California Now ?

The efforts of Bath and Marble to identify an inexpensive and fast hay assay that predicts its energy content resulted in our current California system that predicts the TDN value of hay from its content of ADF (i.e., acid detergent fiber). ADF was selected for four main reasons. It was relatively inexpensive to assay, it was relatively fast to assay, it was relatively repeatable among and within laboratories, and it appeared to be well related to the TDN content of hay. For this reason, California laboratories predict the TDN content of hay by the Bath and Marble UC Davis equation of:

$$\textbf{TDN (90\% of DM)} = (82.38 - (0.7515 \times \%ADF_{(100\% \text{ of DM})}))*0.9$$

Unfortunately ADF reflects, on average, only about 78% of the total structural fiber (i.e., NDF) in alfalfa hay, although this can range between about 70 and 85% in individual samples submitted to California laboratories. Since the total structural fiber is the slowest digesting part of the hay, it is NDF rather than ADF that is the best predictor of the hay's energy content. In other words, two samples of alfalfa hay containing 28% ADF will, on average, contain 35.9% NDF. However if one of the samples actually contains 33.9% NDF and the other actually contains 37.9% NDF, then the sample with the higher NDF will have the lower actual energy value.

Using NDF to Predict Hay Quality More Accurately ?

Advances in analytical methodology have made NDF a much more available and repeatable assay than in the past. Thus, an inherently more accurate equation to predict the energy value of alfalfa hay uses NDF, rather than ADF, by the equation:

$$\textbf{TDN (90\% of DM)} = (82.38 - (0.5964 \times \%NDF_{(100\% \text{ of DM})}))*0.9$$

Overall, this equation will predict the same **average** energy value as the ADF-based equation for any large group of hay samples. However it will better estimate the energy value of individual hay samples. Consider the predicted TDN values of three samples of hay with the same ADF level, but with different NDF levels:

	NDF*	ADF	TDN based on:	
	---- % of DM ----		NDF	ADF
Sample 1 – highest NDF	39.9	28.0	52.8	55.2
Sample 2 – average NDF	35.9	28.0	55.2	55.2
Sample 3 – lowest NDF	32.6	28.0	56.6	55.2

* - These are extreme values for the 28% ADF hay.

These differences in the estimated TDN (i.e., the energy content) are substantial and will affect the milk production level of the cows to which the hay is fed. It is likely that variable levels of NDF in commercial hay samples with the same ADF level is one of the key reasons why some samples of alfalfa hay 'feed better' and some 'feed worse' than their TDN values, calculated from ADF, would suggest.

Keep in mind that even if the laboratory to which you are sending hay samples for analysis is predicting the TDN level of the hay from ADF, you can calculate TDN from NDF yourself, using the equation provided earlier, if your hay analysis includes NDF.

What is on the Horizon Relative to NDF ?

There are two current problems with the use of NDF to predict the TDN content of hay, and both are in the process of being addressed. The first problem is analytical, as there

has been no commonly accepted method for NDF analysis. This has been a major difficulty in the past as each commercial laboratory tended to have a slightly different method to assay for NDF and so NDF values varied among laboratories. In the US, the Association of Official Analytical Chemists (AOAC) is the recognized group that tests and accepts new chemical assays. The NDF procedure is currently being evaluated by the AOAC and it is expected that the procedure will be accepted by the AOAC in the near future. Once this occurs, the variation among commercial laboratories in NDF assays should be substantially reduced. However, the new NDF procedure is available now from D.H. Putnam at UC Davis and all California laboratories are encouraged to adopt it.

The second problem with NDF is biological, as the digestibility of NDF in the rumen of dairy cows is not the same among hay samples (i.e., digestibility of NDF is not the same among and within types of forages). For example, it is clear that NDF in some alfalfa hay samples is more rapidly digested than it is in others. This difference among hay samples reflects the maturity of the hay (i.e., as maturity increases the digestibility of the NDF in the hay tends to decline), the environmental conditions under which it is grown, and the variety of alfalfa. Whatever the cause, it is clear that alfalfa hays containing NDF with higher digestibility will have higher TDN values, as the TDN value of the hay reflects the content of **digestible** NDF in the hay.

The Bottom Line

The authors suggest that:

> *California laboratories* adopt the NDF assay procedure currently being considered by the AOAC, in addition to ADF at this point, and set a date to change to providing TDN values of alfalfa hay on assay reports that are predicted from NDF.
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> *California Hay Growers and Buyers* request NDF analysis of hay samples, become familiar with NDF levels of hay, and begin to predict the TDN content of hay from NDF.

The shift to NDF from ADF as a predictor of hay quality has occurred over the past 10 years amongst dairy nutritionists because it is a fundamentally better estimator of hay quality and productive performance of dairy cows. As California laboratories shift from ADF to NDF, and as NDF becomes more broadly accepted within the dairy industry, the energy value of commercial lots of alfalfa hay will be predicted more accurately.

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