Forage Digestibility – A Tool to Refine Ration Formulation

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Forages are the foundation upon which economical dairy rations are built. The primary role of forages is to provide fiber. Fiber provides a source of carbohydrates used as an energy source by rumen microorganisms. The volatile fatty acids produced during ruminal fermentation are a major energy source for the cow. Fiber is also essential to stimulate chewing and rumination. Forages also provide a number of nutrients to the cow including protein and minerals.

Fiber content of forages has traditionally been analyzed as either ADF (acid detergent fiber) or NDF (neutral detergent fiber). ADF is related to digestibility and has been used to estimate the energy content of forages. NDF is a better predictor of milk production and dry matter intake. Total ration NDF intake for lactating cows is usually programmed at about 1.2% of bodyweight. Typically, a minimum of 70-80% of this total NDF intake is from forage sources.

In the last few years, there has been renewed interest in both forages and fiber in dairy cattle rations. This interest has centered on the following areas:

1. Revising energy prediction equations.
2. Variations which exist in fiber digestibility.
4. Adjustment of rations to account for variations in fiber digestibility.

A. Energy Prediction Equations

The energy content of forages has traditionally been determined using regression equations based on ADF content. The rationale for this is that lignin which is a component of ADF, is unavailable to the cow. As lignin and ADF increase, digestibility will decrease. The weakness is that the ADF:lignin ratio in forages is not constant.

There are also other components of forages which can influence both digestibility and energy content. Goering and Van Soest (1970) proposed that a summative equation should be used to estimate digestibility. This equation would consider cell walls, cell wall contents and digestibility of the cell contents. This concept has been refined by workers at Ohio State. The most recent description of this approach has been provided by Weiss (1999). This approach to predicting energy values of forages was adopted by the Dairy One Forage Testing Lab in 1996.
B. Variation in Fiber Digestibility

Digestibility of the fiber component of forages varies due to a number of factors including hybrid (variety), maturity, temperature, moisture, fertilization, fermentation and processing methods. Allen and Oba (1996) reported ranges of in vitro NDF digestibility of 25 to 60% for alfalfa and 20 to 60% for corn silage. Table 1 contains data for forage samples from the Northeast. The range in NDF digestibility of these samples is 30-35 units.

What does this variation in NDF digestibility mean in terms of animal performance? Oba and Allen (1999) summarized the results from 13 research studies. Higher levels of dry matter intake and milk production were observed as NDF digestibility increased. The following relationships were derived from this summary.

- A 1 unit increase in NDF digestibility was associated with a 0.37 lb increase in dry matter intake and 0.55 lbs of 4% fat corrected milk.

C. Methods to Measure Fiber Digestibility

There are a number of methods which can be used to measure fiber digestibility. In vivo trials can be conducted with animals. These have value from a research viewpoint but are not practical for routine forage analysis systems. The use of near infrared reflectance spectroscopy (NIR) is also a possibility. This technology should be able to measure digestibility rapidly. The challenge is the investment of resources to develop appropriate and robust calibration equations. Currently, NIR is not a practical option in the Northeast.

There are 2 approaches currently available in the Northeast to estimate fiber digestibility. These are the in vitro and in situ approaches. Both techniques have advantages and disadvantages.

1. In vitro –

A small amount of a dry, ground sample is incubated with rumen fluid and buffer in a temperature controlled system. Currently, this analysis provides an endpoint value for in vitro true digestibility (IVTD) and digestible NDF (dNDF). The dNDF information can then be used in the Weiss equation to predict the NE\textsubscript{i} value of a feed. Table 2 contains IVTD and dNDF values determined at the Dairy One Forage Testing Lab. Note the large range between the high and low values reported.

The advantage of this approach is a relatively quick analysis at a low cost. The analysis is run for 30 hours, which most closely approximates the rumen residence time of forage in a mid-lactation cow. One disadvantage is the use of
a dry, ground sample. This may decrease the difference between samples or
give higher digestibilities than unground, wet samples.

2. **In situ** –

The in situ approach consists of placing a feed sample in a nylon bag and
placing the bag in the rumen. The bag is removed, washed and the quantity of
undigested material determined. From this information, digestibility can be
calculated.

Most labs conduct this analysis using dry, ground samples. However, the
same concern exists when using dry, ground samples as indicated for the in vitro
procedure. An alternative is to use wet, unground samples for this analysis. This
is the method used by the FA.R.M.E. Institute when conducting the in situ
procedure. The use of wet, unground samples can increase the difficulty of
obtaining a representative subsample to place in the nylon bag.

This approach can provide both dry matter and NDF digestibility. An
energy value can be calculated based on measured digestibility. Digestion rate
can also be calculated if nylon bags are removed at varying ruminal incubation
times. This approach can also provide “estimates” of input parameters that can
be used in dynamic models such as CNCPS and CPM-Dairy.

One disadvantage of this approach is the relatively high cost per sample.
In addition, the number of points typically measured are minimal in terms of
mathematically describing a rate of digestion curve. The “estimates” provided
can be used provided some caution is used.

**D. Adjustment of Rations**

The primary use of dNDF is the evaluation and or adjustment of rations in
which animal performance is not matching predicted or formulated levels. There
are a number of steps which need to be taken in approaching this type of
situation. These steps include:

1. **Forage analysis** –
   - Does it represent the current forage fed?
   - Was a representative sample taken and provided to the
     forage testing lab?

2. **Feed Management** –
   - Was the ration properly formulated?
   - Is the ration formulated actually being mixed and fed?
   - Are there refusals?
What do the refusals look like?
Are signs of BBD (bare bunk disease) present?
Are adjustments made for changes in forage and feed dry matters?
Is adequate water available?
Is a TMR fed?
How much opportunity is there for cows to select feeds and rebalance the ration?
What is the incidence of mastitis?
What is the incidence of metabolic disorders?
Have you evaluated peak milk and persistency?
What about forage particle size, chewing and rumination?
How does body condition change postcalving?
Has the farm recently changed silos or other forage sources?
How consistent is the forage?
What is the quality of silage fermentation?
Is there adequate feed bunk space per cow?
Are molds or mycotoxins present?
Does the actual concentrate use rate match the calculated use rate?

This is only a short list of items and areas which should be evaluated when herd performance is off. I would not suggest the use of either the in vitro or in situ technique to measure forage digestibility before the above items are evaluated and corrected if needed.

If all of the above look okay, then I would consider determining fiber digestibility. In most situations, the in vitro procedure which provides an end point value may be adequate. Sniffen and Emerick (1998) suggest the following guidelines to interpret these results:

**Alfalfa**
- > 40% dNDF = Excellent
- 30-40% dNDF = Good
- < 30% dNDF = Poor

**Grass**
- > 45% dNDF = Excellent
- 35 - 45% dNDF = Good
- < 35% dNDF = Poor

**Corn silage**
- > 45% dNDF = Excellent
- 35-45% dNDF = Good
- < 35% dNDF = Poor
These guidelines are preliminary and somewhat tentative. The above guidelines are only appropriate for use with in vitro analysis. This information can also be used to recalculate the feed NE\(_i\) content.

The in situ technique can be used when an index of rate of digestion is needed rather than only an end point value. This situation would primarily be when “estimated” rate of digestion values are desired to be used as input into a program such as CNCPS.

What do you do if fiber digestibility is indeed low? There are a number of options which exist depending on the specific farm. These include:

- Eliminate or decrease the feeding rate of the low digestibility forage.
- Increase the feeding rate of other forages.
- Substitute a digestible fiber source (beet pulp, soy hulls, etc.) as a partial forage replacement. If this is done, maintain actual forage NDF intake at 0.75% of body weight or more.

The results of using this approach in the field are still limited. In some cases, there has been little change in herd performance. There have also been reports of milk production increases of 3 to 10 lbs of milk per cow per day (Siciliano-Jones and St. Pierre, 1997). Logically, adjustment of rations for variations in fiber digestibility should enhance DMI and milk production.
Table 1. Variation in NDF and Digestibility of Northeastern US Forages$^{a,b}$

<table>
<thead>
<tr>
<th>Feed</th>
<th>Number of Samples</th>
<th>Analysis</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
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<tbody>
<tr>
<td>Alfalfa silage</td>
<td>35</td>
<td>NDF, %</td>
<td>50.6</td>
<td>35.88</td>
<td>69.71</td>
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<td></td>
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<td>DNDF, %$^c$</td>
<td>51.9</td>
<td>36.93</td>
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<td></td>
<td></td>
<td>DMD, %$^d$</td>
<td>75.15</td>
<td>56.03</td>
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<td>Corn silage</td>
<td>50</td>
<td>NDF, %</td>
<td>46.65</td>
<td>32.09</td>
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<td></td>
<td></td>
<td>DNDF, %</td>
<td>43.45</td>
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<tr>
<td></td>
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<td>DMD, %</td>
<td>73.87</td>
<td>61.79</td>
<td>85.00</td>
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<tr>
<td>Grass silage</td>
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<td>NDF, %</td>
<td>61.35</td>
<td>47.61</td>
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<td></td>
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<td>DNDF, %</td>
<td>48.21</td>
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<td></td>
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<td>DMD, %</td>
<td>67.59</td>
<td>53.37</td>
<td>83.68</td>
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</table>

$^a$Miner Institute Research Report 98-8
$^b$In vitro analysis
$^c$Digestibility of NDF
$^d$Dry matter digestibility

Table 2. In vitro digestibility results $^a$

<table>
<thead>
<tr>
<th>Feed</th>
<th>Analysis</th>
<th>Average</th>
<th>Standard Deviation</th>
<th>Low Value</th>
<th>High Value</th>
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<tr>
<td>Hay</td>
<td>IVTD$^b$, %</td>
<td>67.5</td>
<td>11.2</td>
<td>45.3</td>
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<td>dNDF$^c$, %</td>
<td>41</td>
<td>9</td>
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<td></td>
<td>IVTD-NE$_i$$^d$, Mcal/lb</td>
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<td>.11</td>
<td>.32</td>
<td>.70</td>
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<tr>
<td>Haylage</td>
<td>IVTD, %</td>
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<tr>
<td></td>
<td>dNDF, %</td>
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<td>8</td>
<td>28</td>
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<tr>
<td></td>
<td>IVTD-NE$_i$, Mcal/lb</td>
<td>.57</td>
<td>.11</td>
<td>.28</td>
<td>.71</td>
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<tr>
<td>Corn silage</td>
<td>IVTD, %</td>
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<td>.12</td>
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<td>TMR</td>
<td>IVTD, %</td>
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<td>dNDF, %</td>
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<td>IVTD-NE$_i$, Mcal/lb</td>
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<td>.04</td>
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<td>.81</td>
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$^a$Source: P. Sirois, Dairy One Forage Lab
$^b$In vitro true digestibility
$^c$Digestible NDF
$^d$NE$_i$ calculated from the dNDF results