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Using NDF and ADF To Balance Diets

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In University of Missouri Agricultural guides G3150 and G3160 we explained how detergent solutions are used to measure forage fiber. The guides show how neutral detergent solution can be used to measure neutral detergent fiber (NDF). NDF represents the total plant fiber or cell wall including hemicellulose, cellulose and lignin.

These guides also show how acid detergent solution can be used to measure acid detergent fiber (ADF), which contains cellulose and lignin. Both ADF and NDF data help to more accurately estimate feed intake, energy values and animal performance.

Using NDF to predict forage intake

NDF reflects the bulkiness of a forage. Because forage fiber is bulky, there is a limit to the amount of NDF that will fit into a cow's rumen (first stomach). When that limit is reached, she will stop eating. There's no more room until a significant portion of the fiber in the rumen is digested and/or passes on to the lower gut.

We have measured the amount of NDF in the rumens of fistulated cows fed various forage diets. A typical 1,300-pound Holstein will contain 14-16 lbs. of forage NDF (on a dry matter basis) in her rumen. Thus, she can hold a maximum of 1.0 - 1.2 percent of her body weight (BW) as NDF. Other researchers have reported NDF intakes of 1.1-1.2 percent of BW for typical forages, although it appears that very high quality forages and certain by-products may be associated with 1.5 percent or more.

The proportion of NDF to BW is an important fundamental relationship. If we know the percent of NDF in the forage and the cow's body weight, we can estimate maximum forage dry matter intake (DMI). A 1,000-pound cow eating hay with an NDF of 65 percent on dry matter basis and a dry matter of 90 percent would be expected to consume a maximum forage intake of 18.8 lbs. (on as-fed basis):

1,000-lb. cow x .011 = 11.0 lbs. NDF Intake (NDFI)

$$\frac{\text{11.0 lbs. NDFI}}{\text{.65 NDF in forage}} = \text{16.9 lbs. forage DMI}$$

or more simply:

$$\text{DMI} = \frac{1.1 \times BW}{\text{NDF \%}} = \frac{1000 \times 1.1}{65}$$

$$= \text{16.9 lbs. DMI}$$

$$\frac{\text{16.9 lbs. forage DMI}}{\text{.90 DM}} = \text{18.8 lbs. on as fed basis}$$

These assumptions are for dairy cows. Beef cows appear to eat about 10 percent less forage than dairy cows and estimates of forage intake are set at 90 percent that of dairy cows.

Expected forage DMI for various BWs and forage NDF percents are in Table 1. These numbers should be considered maximums for cows eating diets containing 50 percent or more forage. If forage quality is very high, or if the animal is a very high producing dairy cow or rapidly growing beef cow or if it is very cold, NDFI and feed intake could increase 10-20 percent.

On the other hand, if cows are eating large amounts of grain or if the environment is very hot, intake could be depressed 10 percent or more. By-product feeds, such as corn gluten feed and soybean hulls, and very high quality (very immature) forages also are exceptions, since 2.0 percent of BW as NDFI are possible. However, for most forages and quality stages 1.1-1.2 percent BW appears reasonable.

Using ADF to estimate NEL or TDN

Energy content of a forage often is estimated from ADF content. Energy can be expressed as total digestible nutrients (TDN), digestible energy (DE),

metabolizable energy (ME), net energy of lactation (NEL), net energy of maintenance (NEM) or net energy of gain (NEG).

TDN is expressed in percent, while DE and ME are expressed in energy units (i.e., Mcal/lb.); these usually are used to formulate swine, sheep and horse diets. For this discussion we will use NEM, NEL, NEG and TDN to formulate diets for cattle. There are separate equations for estimating these four energy values; they all are based on ADF percent. The basic assumption is that high quality forage has low ADF and NDF compared to low quality forage. High quality forage digests more completely and has higher energy values (Fig. 1). The relationships among TDN, NEL, NEM and NEG for high quality alfalfa (ADF = 30%) and two low quality alfalfas (ADF = 40%) are illustrated in Table 2. Although each forage species (i.e., legumes, grasses, sudan-sorghums, corn silage, etc.) has its own separate equations for predicting energy values, all equations are based on a negative correlation with ADF. Most testing laboratories use computer programs containing these equations to estimate the appropriate value. However, not all labs use the same equations for a particular forage species. Thus, if you sent the same forage sample to several different testing labs, the results may not agree.

An example follows:

For legumes:

$$NEL = 1.037 - 0.0124 \times ADF$$

$$NEM = 1.037 - 0.0124 \times ADF$$

$$NEG = [2.54 - (2.42 / (NEM \times 2.2))] / 2.2$$

$$TDN = 8 + 86 \times NEL$$

For alfalfa with an ADF of 34%, then;

NEL = .62
NEM = .62
NEG = .35
TDN = 61

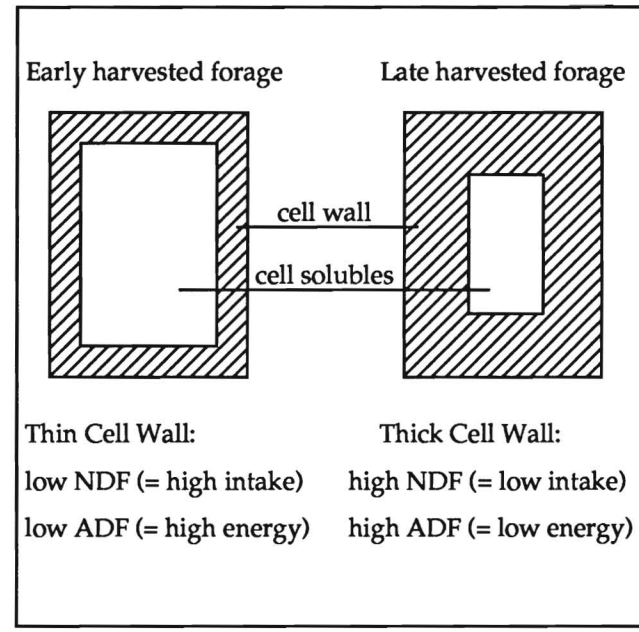

Figure 1. Relationship between harvest stage and fiber content.

Table 1. Expected cell wall and forage dry matter intake.

		NDF Intake		Forage Dry Matter Intake	
Body Wgt.	Forage NDF	Dairy Cow	Beef Cow	Dairy Cow	Beef Cow
Lbs.	%	-- Lbs.--		-- Lbs. --	
1,000	40	11.0	9.9	27.5	24.8
	50	11.0	9.9	22.0	19.8
	60	11.0	9.9	18.3	16.5
1,200	40	13.2	11.9	33.0	29.7
	50	13.2	11.9	26.4	23.8
	60	13.2	11.9	22.0	19.8
1,400	40	15.4	13.9	38.5	34.7
	50	5.4	13.9	30.8	27.7
	60	15.4	13.9	25.7	23.1

Table 2. Relationships between energy values for alfalfa.

Term	ADF %	
	30.00	40.00
NEL	0.66	0.54
NEM	0.66	0.54
NEG	0.40	0.23
TDN	65	55

Balancing diets using NDF and ADF

Using the above information, we can balance diets maximizing forage intake. Assume a 1,000-pound dairy cow producing 60 lbs. of milk or a 1,000-pound beef cow of superior milking ability in early lactation eating low quality, legume forage (NDF = 65% and ADF = 42% of DM) (Table 3):

- Cell wall intake = 1,000 x .011 - 11.0 lbs.
- Forage DMI = 11.0 lbs./.65 NDF
  = 16.7 lbs. DM (18.8 lbs. as fed)
- Forage NEL or NEM = .52 Mcal/lb.
  (based on ADF)
- Forage NEL or NEM
  intake = .52 x 16.7 lbs.
  = 8.7 Mcal
- Concentrate NEL or NEM = .85 Mcal/lb.
- Concentrate needed
  for dairy cow = 29.1 lbs. (as fed)
- Concentrate needed
  for beef cow = 9.3 lbs. (as fed)

This is a relatively high concentrate ration. We can increase forage intake if we feed a high quality, legume forage (NDF = 45% and ADF = 30%) (Table 4).

- Cell wall intake = 1,000 x .011
  = 11.0 lbs.
- Forage DMI = 11.0 lbs./.45
  = 24.4 lbs. DM (27.1 lbs. as fed)
- Forage NEL = .66 Mcal/lb.
- Forage NEL intake = .66 x 24.4
  = 16.1 Mcal
- Concentrate needed for dairy cow
  = 19.4 lbs. (as fed)
- Concentrate needed for beef cow = 0 lb.

Table 3. Concentrate supplementation needed by a dairy and beef cow fed low quality forage.

Low Quality Forage			
Dairy Cow		Beef Cow	
Use	NEL Needed	Use	NEM Needed
maintenance	10.0 Mcal	maintenance	9.0 Mcal
milk (60 lbs.)	21.0 Mcal	milk	6.0 Mcal
Total	**31.0 Mcal**	**Total**	**15.0 Mcal**
Forage DMI	16.7 lbs.	Forage DMI	15.2 lbs.
Forage NEL	8.7 Mcal	Forage NEM	7.9 Mcal
Energy needed from grain	22.3 Mcal (31.0-8.7)	Energy needed from grain	7.1 Mcal (15.2-7.9)
Amt grain (22.3 + .85 Mcal/lb.)	26.2 lbs. (DM)	Amt grain (7.1 + .85 Mcal/lb.)	8.4 lbs. (DM)
29.1 lbs. (as fed) = 26.2 + .90		9.3 lbs. (as fed) = 8.4 + .90	

Table 4. Concentrate supplementation needed by a dairy and beef cow fed a high quality forage.

High Quality Forage			
Dairy Cow		Beef Cow	
Use	NEL Needed	Use	NEM Needed
maintenance	10.0 Mcal	maintenance	9.0 Mcal
milk (60 lbs.)	21.0 Mcal	milk	6.0 Mcal
Total	**31.0 Mcal**	**Total**	**15.0 Mcal**
Forage DMI	24.4 lbs.	Forage DMI	22.0 lbs.
Forage NEL	16.1 Mcal (24.4 x .66)	Forage NEM	14.5 Mcal
Energy needed from grain	14.9 Mcal (31.0-16.1)	Energy needed from grain	.5 Mcal
Amt. grain	17.5 lbs.(DM) 19.4 lbs.(as fed)	Amt. of grain	.6 lb. (DM) .7 lb. (as fed)

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