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Making Forage Analysis Work for You in Balancing Livestock Rations and Marketing Hay

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Forage and grain samples differ in their chemical composition and digestibility. These qualities, along with the amount animals eat and the efficiency of their metabolism, largely determine animal performance in terms of meat, milk, and wool production. While less accurate than directly measuring these indicators of animal performance, forage analysis can help producers estimate forage nutritive value in terms of livestock production. These estimates can be used in ration balancing to improve animal production and cost effectiveness of rations.

Since the mid-1800s, scientists have evaluated forage by using the proximate analysis—or crude fiber—system. More recently, experiments have shown that detergent analysis systems—acid detergent fiber (ADF) and neutral detergent fiber (NDF)—provide better estimates of forage digestibility and intake. These fractions may be determined either by wet chemistry or by near infrared reflectance spectroscopy (NIRS).

The detergent system measures basic components of plant structure and relates them to animal digestion and production. The system uses detergents to separate feed and forage dry matter into cell contents and various fiber (cell wall) fractions. Cell contents are those portions an animal can digest completely and quickly. The concentration of cell contents ranges from 90 percent in corn grain to 60 percent in immature alfalfa to 25–35 percent in grasses.

Fiber fractions break down incompletely and more slowly during digestion. Two major fiber fractions are acid detergent fiber, used to estimate forage digestibility, and neutral detergent fiber, used to estimate intake. The fractions are determined by using different detergent solutions to remove various compounds and leave the fiber fractions. Components of the ADF and NDF fiber fractions appear in Figure 1.

Recently these fractions have been accurately estimated by near infrared reflectance spectroscopy (NIRS). The big advantage of NIRS is speed: laboratories can obtain results in 10 to 15 minutes rather than the several days required for wet chemistry. This speed has made possible quality-tested hay auctions and harvesting by quality. A note of caution: NIRS results are only as good as the calibration curve in the test instrument. Forage analysis laboratories develop a calibration curve from a set of samples of known analysis. Analyzing a sample type different from those included in the original calibration set may produce erroneous results. Unless you know that your uncommon forages (e.g., sorghum silage, trefoil hay, total mixed rations) are included in the calibration curve, request wet chemistry rather than NIRS when you ask for an analysis of uncommon forages.

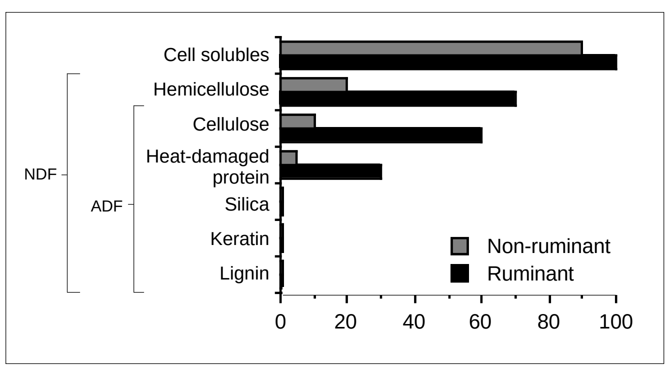
Forage Analysis Terms

Laboratories provide a forage analysis report of nutritional information that includes the terms listed below.

Dry Matter (DM) is the percentage of feed that is not water. For instance, a sample of haylage containing 45 percent DM is 55 percent water. Water in a sample tends to lower its nutrient content in proportion to the amount of water present. For example, a sample containing 20 percent crude protein on a 100 percent "dry matter" basis has 9 percent—45 percent of 20—crude protein on an "as is" basis. This illustrates the importance of comparing quality and price of feedstuffs on a dry matter basis.

Acid Detergent Fiber (ADF) is the percentage of highly indigestible and slowly digestible material in a feed or forage. It contains cellulose as well as silica and lignin, which are associated with low digestibility in

Figure 1. Digestibility of forage components by ruminants and non-ruminants



feeds. The lower the ADF, the more of the feed an animal can digest. Thus, a low ADF percentage is desirable. The ADF fraction will also contain pectin if it was present in the original forage (e.g., alfalfa) which may artificially raise the ADF percentage. ADF differs from crude fiber in that ADF contains silica but no hemicellulose, while crude fiber contains hemicellulose but no silica.

Neutral Detergent Fiber (NDF) is the percentage of cell walls or fiber in a feed. It includes acid detergent fiber (except pectin) and hemicellulose (Figure 1). NDF is only partially available to animals. It is inversely related to animal intake: the lower the NDF percentage, the more forage an animal will potentially eat. Thus, a low percentage is desirable as long as a certain minimum fiber level in the ration is met.

Digestible Dry Matter (DDM) is an estimate of the percentage of the feed or forage that is digestible, based on feeding trials with animals. It can be estimated from ADF content of feedstuffs.

Dry Matter Intake (DMI) is an estimate of the relative amount of forage an animal will eat when only forage is fed. A practical estimate of forage intake at average grain levels is obtained by multiplying cow weight in pounds by .0085 and then dividing by NDF concentration expressed as a decimal (e.g., for a 1350-pound cow being fed forage with an NDF content of 40 percent, estimated intake is 28.7 lbs; 1350 x .0085/.40 = 28.7 lbs).

Digestible Dry Matter Intake (DDMI) is an estimate of how much of the dry matter an animal will consume. DDMI also estimates digestible energy intake. DDMI is calculated by multiplying DDM by DMI and dividing by 100.

Relative Feed Value (RFV) is an index used to compare the quality of forages. It is calculated by dividing DDMI by a constant, 1.29, based on forage quality of alfalfa between three-fourths and full bloom.

Crude Protein (CP) is determined by measuring total nitrogen and multiplying it by 6.25. CP is a mixture of true protein and nonprotein nitrogen. It indicates the capacity of the feed to meet an animal's protein needs. Generally, moderate to high CP is desirable since this reduces the need for supplemental protein. Forage cut early, with a high percentage of leaves and/or with a high proportion of legume, has a high CP content.

Acid Detergent Fiber - Crude Protein (ADF-CP) is a measure of the unavailable protein, which is not able to be digested by the rumen. Recent research has shown that some ADF-CP is available as bypass protein and may actually be beneficial in high performance rations. Formation of ADF-CP is also called non-enzymatic browning (because the hay or silage turns brown) or Maillard reaction.

Some ADF-CP is present in all forages. Legumes have less ADF-CP than grasses, and immature forages have less ADF-CP than mature forages. Most ADF-CP results from heating during improper preservation, which causes amino acids to condense with sugar residues. This reaction usually makes the forage more palatable but can reduce the forage's nutritive value for cattle since a portion of the protein becomes unavailable. ADF-CP is determined by measuring nitrogen in acid detergent fiber—also called acid detergent insoluble nitrogen (ADIN)—and multiplying by 6.25.

A ratio of ADF-CP to CP (multiplied by 100) less than 10 reflects good harvest and storage practices. A ratio of 15 or higher indicates that the moisture content at harvest, storage conditions, or both, resulted in excessive heating.

Adjusted Crude Protein (ACP) is the CP available for animal use. It is composed of the ADF-soluble protein and a portion of the ADF-CP. This value, rather than crude protein, should be used for balancing rations when the ratio of ADF-CP to CP is 15 or higher. Adjusted crude protein is calculated as follows:

If ADF-CP/CP ratio (x100) is less than 15,
then ACP = CP.
e.g., if CP = 10 and ADF-CP = 1.1
ADF-CP/CP = (1.1/10) x 100 = 11
so ACP = CP = 10

If ADF-CP/CP ratio (x100) is 15 to 20, inclusive,
then ACP = CP–(((Ratio–7)/100) x CP).
e.g., if CP = 10 and ADF-CP = 1.9
ADF-CP/CP = (1.9/10) x 100 = 19
so ACP = 10–(((19–7)/100) x 10) = 8.8

If ADF-CP/CP ratio (x100) is greater than 20,
then ACP = CP – ADF-CP.
e.g., if CP = 10 and ADF-CP = 2.3
ADF-CP/CP = (2.3/10) x 100 = 23
so ACP = 10–2.3 = 7.7

Calcium (Ca), Magnesium (Mg), Phosphorus (P), and Potassium (K) are expressed as a percentage of each nutrient in the feed on a dry matter basis. Ca is higher in legumes than in grasses. K and P are usually higher under adequate fertility programs. These nutrients can be either measured directly, as in soil and tissue analysis, or indirectly. NIRS cannot "see" minerals but determines their levels indirectly by association with organic constituents. Therefore, NIRS determination of minerals, while adequate for ration balancing, is less accurate than direct determinations of minerals such as those used in tissue testing for fertilizer recommendations.

How to Use Forage Quality Measures

Forage production is big business in Wisconsin. Forage quality can greatly affect animal production and, therefore, farm profitability. Nutrient analysis of forage is necessary for accurately balancing rations and figuring lowest costs. Normal composition ranges for forages appear in Table 3.

Ration balancing uses CP, ADF, NDF, K, Ca, and P as direct inputs for cattle, sheep and horses. Farmers can use ADF and NDF values to estimate digestibility and intake for each forage lot tested. The concentration of NDF in forage can be used to specify the minimum and maximum proportion of forage needed in total mixed rations (refer to Table 1).

A large amount of hay is bought and sold throughout Wisconsin. Quality factors are as important when purchasing hay as when producing it. When buying hay, visual appraisal of quality can be deceiving. Quality is important to the seller as well—high-quality hay tends to sell at a premium. Market hay grades are based on forage quality and reflect forage species, composition and maturity (refer to Table 2). Legumes tend to grade highest, followed by legume/grass mixtures, grasses and heavily weathered forage.

Hay dealers report purchasing much of their hay one day and selling it the next. Time doesn't permit obtaining a wet chemistry analysis for forage quality. NIRS analysis provides a rapid, precise evaluation of hay and haylage. Mobile NIRS vans permit on-site testing at hay auctions where dairy and livestock producers can obtain a reasonable estimate of how their animals will perform on each hay lot.

Table 1. Influence of Neutral Detergent Fiber on forage limits in ration formulation

	Forage NDF%					
	40	**45**	**50**	**55**	**60**	**65**
Type of Cow		— — — —	minimum % forage in ration — —			
Milking	53	46	42	38	35	32
Dry	*	75	72	65	60	55
Lactation stage		— — — —	maximum % forage in ration — —			
Early, over 3 lb fat/day	65	58	52	47	43	40
Mid, 1.7-2.4 lb fat/day	80	71	64	58	53	49
Late, under 1.5 lb fat/day	95	84	76	69	63	58
Dry	100	100	100	91	83	77

* Not recommended as sole feed.

Table 2. Legume, grass and grass legume mixture quality standards

	Analysis[a]					
Quality Standard	**CP**	**ADF**	**NDF**	**DDM[b]**	**DMI[c]**	
	—— % of Dry Matter ——			**% of DM**	**% of BW**	**RFV[d]**
Prime	>19	<31	<40	>65	>3.0	>151
1	17-19	31-35	40-46	62-65	3.0-2.6	151-125
2	14-16	36-40	47-53	58-61	2.5-2.3	124-103
3	11-13	41-42	54-60	56-57	2.2-2.0	102-87
4	8-10	43-45	61-65	53-55	1.9-1.8	86-75
5	<8	>45	>65	<53	<1.8	<75

[a]Analysis associated with each standard: CP = Crude Protein; ADF =Acid Detergent Fiber; NDF = Neutral Detergent Fiber

[b]DDM = Digestible Dry Matter = 88.9–(0.779 x ADF)

[c]DMI = Dry Matter Intake (% of body weight) = 120/(forage NDF)

[d]Relative Feed Value = (DDM x DMI)/1.29

Table 4. Composition of several common forages

Crop & Harvest	CP	ADF	NDF	TDN	RFV	ADF-CP	ADF-CP/CP	Ca	P	Mg	K
Method	**% Dry Matter (DM)**					**% DM**		**% Dry Matter (DM)**			
Alfalfa, red clover, trefoil as hay or silage											
Immature, Bud	19–24	28–32	38–42	63–67	141–164	.6–.8	5–10	1.2–1.6	.27–.32	.28–.40	2.0–3.0
Early Bloom	17–20	31–35	40–46	61–64	124–151	.8–1.0	7–10	1.1–1.3	.25–.30	.28–.36	2.0–2.7
Mid Bloom	14–20	35–42	47–52	56–60	100–122	.9–1.2	9–11	1.0–1.2	.23–.28	.28–.32	1.7–2.5
Mature	13–15	41–45	53–60	53–57	83–100	1.0–1.3	10–12	1.0–1.2	.21–.26	.26–.30	1.7–2.3
Legume-grass mixtures, over 50% legume, hay and silage											
Immature, Bud	18–24	28–32	43–48	63–67	124–145	.6–.8	5–10	0.8–1.3	.27–.32	.25–.40	1.9–3.0
Early Bloom	16–18	31–35	46–52	60–64	110–131	.8–1.0	7–11	0.7–1.2	.23–.30	.25–.36	1.8–2.7
Mid Bloom	13–15	35–40	50–56	57–60	96–115	.9–1.2	11–13	0.7–1.0	.21–.28	.25–.32	1.7–2.5
Mature	11–13	41–45	54–62	53–56	81–98	1.0–1.3	12–16	0.7–0.9	.19–.26	.23–.30	1.6–2.3
Grasses, brome, orchard, timothy, ryegrass, hay and silage											
Vegetative	17–20	28–35	48–54	60–67	106–130	.5–1.1	7–10	0.5–0.8	.25–.35	.20–.32	1.5–2.5
Early Heading	14–16	35–40	52–60	57–60	90–110	.5–1.1	8–12	0.4–0.7	.23–.30	.20–.30	1.5–2.5
Heading to Bloom	10–13	40–45	59–66	53–56	76–90	.5–1.1	10–15	0.4–0.6	.20–.27	.18–.27	1.5–2.5
Mature	7–9	45–50	66–75	49–52	62–76	.5–1.1	11–18	0.3–0.5	.15–.23	.16–.25	1.5–2.5
Corn silage, whole plant (field or sweet corn)											
75% Silk	9–11	28–31	50–56	62–67	108–124	.4–.9	8–12	.20–.35	.15–.25	.15–.25	0.7–1.2
Milk	8–10	26–31	48–56	64–66	107–133	.4–.9	9–14	.20–.35	.15–.25	.15–.25	0.7–1.2
Dough	7–10	24–30	45–53	65–68	115–145	.4–.9	10–15	.20–.35	.15–.25	.15–.25	0.7–1.2
Physically Mature	7–9	22–30	40–53	65–71	115–167	.4–.9	10–15	.20–.35	.15–.25	.15–.25	0.7–1.2
Few or No Ears	6–9	31–38	53–65	59–65	85–113	.4–.9	12–18	.20–.35	.15–.25	.15–.25	0.7–1.2
Corn stalks, silage											
Good Quality	5–7	35–40	60–70	55–60	77–96	.5–.8	15–20	.30–.40	.10–.15	.10–.20	1.0–1.5
Cornstalks, dry											
Good Quality	5–7	35–40	60–70	55–60	77–96	.5–.8	15–20	.30–.40	.10–.15	.10–.20	1.0–1.5
Fair	4–6	37–45	65–70	53–58	71–86	.5–.8	15–20	.30–.40	.10–.15	.10–.20	1.0–1.5
Poor	4–6	42–50	65–75	49–53	62–80	.5–.8	15–20	.30–.40	.10–.15	.10–.20	1.0–1.5
Small grain, hay or silage											
Vegetative	12–17	31–35	53–60	60–64	96–114		8–12	.40–.60	.20–.30	.20–.25	1.0–1.5
Heading	9–12	35–45	55–65	53–60	77–104		10–14	.40–.60	.20–.30	.20–.25	1.0–1.5
Dough	9–11	37–50	60–70	48–57	66–93		10–16	.40–.60	.20–.30	.20–.25	1.0–1.5

Note: Heat-damaged forage increases Crude Protein, Acid Detergent Fiber, Neutral Detergent Fiber and Acid Detergent Fiber-Crude Protein, it decreases Digestible Dry Matter. Heat damage reduces the spread between Acid Detergent Fiber and Neutral Detergent Fiber.

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