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Interpreting Hay and Haylage Analysis

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Feed test results can be used to: (1) balance rations, (2) improve future crop management if present forage is of unsatisfactory quality, and (3) determine equitable prices for feedstuffs based on nutritive value.

Results of analysis are expressed on an “as-received” and on a “100% dry matter (DM)” basis. As-received is sometimes also referred to “as-fed” or “fresh.” It includes the water or moisture in the feed. Nutrients expressed on this basis represent the nutrient content of the feed when it was received at the lab.

Dry matter basis means all moisture has been removed. The nutrient concentration is that which is contained in the dry matter portion of the feed. Values reported on a dry matter basis are always larger than the as-received values. To convert from as-received to dry matter, use the following formula:

$$\frac{\text{Nutrient (as received basis)} \times 100}{\% \text{ DM}} = \text{Nutrient (DM basis)}$$

For example, if a sample of haylage (55% DM) contains 11.0% crude protein (CP) on an as-received basis, it contains 20.0% (CP) on a dry matter basis:

$$\frac{11.0\% \text{CP} \times 100}{55\% \text{ DM}} = 20\% \text{CP}$$

Moisture/Dry Matter (DM)

Moisture is the amount of water in the feed. Percent moisture = 100 - % DM. Dry matter is the percentage of feed that is not water. Percent DM = 100 - % moisture. A sample of haylage with 55% dry matter contains 45% water.

Crude Protein (CP)

Crude protein is termed “crude” because it is not a direct measurement of protein but is an estimation of total protein based on nitrogen (N) in the feed ($N \times 6.25 =$

crude protein). Crude protein includes true protein and non-protein nitrogen (NPN) such as urea nitrogen and ammonia nitrogen. The crude protein value provides no information about amino acid composition, intestinal digestibility of the protein, or its rumen degradability.

Heat Damaged Protein

Excessive moisture in hays or too little moisture in haylages may result in heating, caramelizing, or browning of the forage. Heat damaged forages are characterized by a brown to black color and a sweet caramel-tobacco aroma. Some proteins become bound with sugars during heating, making both protein and sugar indigestible to animals. These bound proteins are measured in the acid detergent fiber fraction and are termed Acid Detergent Protein or Heat Damaged Protein. Palatability is often increased because sugars turn into syrup during heating. Even though animals may readily consume this sweet-smelling forage, their performance can be negatively affected.

Acid Detergent Fiber (ADF)

ADF consists primarily of cellulose, lignin, and acid detergent fiber crude protein. It is closely related to any indigestibility of forages and is the major factor when calculating energy content of feeds. The greater the ADF the less digestible the feed and the less energy it will contain.

Neutral Detergent Fiber (NDF)

The total fiber content of a forage is contained in the NDF or cell walls. This fraction contains cellulose, hemicellulose, and lignin. NDF gives the best estimate of the total fiber content of a feed and is closely related to feed intake. As NDF values increase, total feed intake will decrease. It is generally assumed ruminants will eat a maximum total NDF of close to 1.2% of their body weight. Grasses will contain more NDF than legumes at a comparable stage of maturity.

Digestible NDF 48 (dNDF)

The importance of measuring dNDF has been only recently recognized. Fiber digestibility differs between legumes and grasses harvested at a similar stage of maturity and even for the same species grown under different weather conditions. By digesting NDF more rapidly, ruminants can move more feed through their rumen faster, thus allowing for greater DMI and enhanced animal performance. Decreases in dNDF are usually a reflection of higher lignin content in the NDF fraction. dNDF48 is measured from an in vitro NDF digestion for 48 hours.

Lignin

Lignin is a polymer component of the plant cell walls that provides rigidity and structural support to plants. It cannot be digested by animal enzymes. It increases as plants mature and is higher when the same plant species grows under warm weather conditions. The higher the lignin content of a forage, the lower the dNDF.

Neutral Detergent Fiber Digestibility (NDFD)

NDFD is dNDF expressed as a percent of NDF. Therefore

$$\text{NDFD} = \text{dNDF}/\text{NDF} \times 100$$

Minerals

Calcium (Ca), phosphorus (P), magnesium (Mg), and potassium (K) values are expressed as a percentage of each in the feed.

Ash (ASH)

Ash is the residue remaining after all organic matter in a sample is completely incinerated, thus $100 - \text{ASH} = \text{organic matter}$. It comprises all inorganic matter (or mineral matter) in the feed, as well as inorganic contaminants, such as soil, sand, or dirt.

Net Energy for Lactation (NE_l)

Net energy for lactation is the term used by the NRC (National Research Council) for assessing the energy requirements and feed values for lactating cows. It is usually expressed as megacalories per pound (Mcal/lb) or megacalories per kilogram (Mcal/kg).

Net Energy for Maintenance (NE_m) and

Net Energy for Gain (NE_g)

The net energy system used by NRC for beef cattle assigns energy values to each feedstuff and subdivides animal requirements for energy. Feed energy is used less efficiently for depositing new body tissue than for maintaining existing body tissue. NE_m is the net energy value of feeds for maintenance. NE_g is the net energy value of feeds for the deposition of body tissue, growth, or gain. Both NE_m and NE_g are needed to express the total energy needs of growing cattle. They are usually expressed as megacalories per pound (Mcal/lb) on SDSU lab reports and can also be expressed as megacalories per kilogram (Mcal/kg).

Crude Fat

Crude fat is also known as ether extract (EE). This term comprises all substances that are soluble in ether (thus the term ether extract). Although crude fat will mainly contain lipids, it will also include other soluble substances such as waxes and fat-soluble vitamins. It is high in energy when the fraction represents primarily lipids.

Nonfibrous carbohydrates (NFC)

NFC represents carbohydrates of high digestibility that are not recovered in the NDF fraction and are calculated as:

$$\text{NFC} = 100 - (\text{CP}\% + \text{NDF}\% + \text{EE}\% + \text{ASH}\%)$$

Total Digestible Nutrients (TDN and TDN1X)

TDN represents the sum of digestible crude protein, digestible carbohydrates, and digestible fat (fat is multiplied by 2.25 to compensate for its higher energy content). Since feeds are utilized differently by different species, percent TDN on a feed is different for each species. TDN is highly correlated with energy content in feeds.

TDN is estimated in many different ways. TDN in SDSU lab reports is estimated from the ADF content of feeds by various equations depending upon type of hay. TDN1X is estimated using NFC, protein, crude fat, NDF, and NDFD. The equation for TDN1X is:

$$\text{TDN1X} = (\text{NFC} \times 0.98) + (\text{PROTEIN} \times 0.93) + (1.50 \times 0.97 \times 2.25) + ((\text{NDF} - 2) \times (\text{NDFD}/100)) - 7$$

Digestible Dry Matter (DDM)

DDM is an estimate of the total digestibility of a legume, legume/grass, or grass forage, hay, or haylage. DDM is calculated from ADF values and can replace TDN. The more ADF in a feed, the lower the DDM value will be.

$$\text{DDM}\% = 88.9 - (0.779 \times \text{ADF}\%)$$

Dry Matter Intake (DMI AND DMI1)

DMI is an estimate of the amount of feed an animal will consume in percent of body weight. DMI is calculated using NDF, and DMI1 is calculated using NDF and NDFD. The more NDF in a forage, the less of it an animal can consume. Research indicates maximum feed intake occurs when NDF is 1.2 pounds per 100 pounds of body weight. A minimum 75% of NDF in the ration should be forages. DMI (maximum forage intake) is estimated from NDF:

$$\begin{aligned} \text{DMI (\% of body weight)} &= 120/\text{NDF}\% \\ \text{DMI1 (\% of body weight)} &= (((0.0120 \times 1350)/\text{NDF}/100)) + ((\text{NDFD} - 45) \times 0.374)/1350 \times 100 \end{aligned}$$

Relative Feed Value (RFV)

RFV is an index used to rank hays or haylages based on a calculation of Digestible Dry Matter (DDM) and Dry Matter Intake (DMI). Digestibility and intake are estimated

from ADF and NDF analyses respectively. The number derived from the RFV calculation has no units and is used only as an index to compare different quality hays and/or haylages. Crude protein is not a factor used in the calculation. A forage with an RFV of 100 contains 41% ADF and 53% NDF. The formula for RFV is as follows:

$$RFV = \frac{DDM \times DMI}{1.29}$$

See Table 1 for typical ranges in hay composition.

Table 1. Typical ranges in legume, legume-grass, and grass hay composition.

Quality Standard ¹	Analysis			DDM ² %	DMI ³ % of BW	RFV
	CP	ADF	NDF			
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

¹ Dry matter digestibility (DDM, %) = 88.9 - 0.779 ADF (% of DM).

² Dry matter intake (DMI, % of body weight) = 120/NDF (% of DM).

³ Relative feed value (RFV) = (DDM x DMI)/1.29

Relative Feed Quality (RFQ)

In the RFV index, DDM was estimated from ADF, which does not account for differences in fiber digestibility. In the RFQ index, NDFD is used to calculate TDN1X in place of DDM, thus reflecting differences in fiber digestibility of hays and haylages.

$$RFQ = (DMI \text{ as a \% of BW}) \times (TDN1X \text{ as a \% of DM}) / 1.23$$

The 1.23 divisor adjusts the equation to have a mean and range similar to RFV.

The RFQ index reflects differences in growing conditions due to ambient temperatures, which impact dNDF. Grasses are high in NDF, but that fiber typically is highly digestible. Grasses should be evaluated more accurately when tested for RFQ instead of RFV. In summary:

- Fiber is more digestible when grown under cooler conditions. Therefore:

First cutting will tend to have more highly digestible fiber than later cuttings growing under higher temperatures.

The same crop grown in the Midwest will tend to have more digestible fiber than when grown in states to the south.

Alfalfa grown in higher mountain valleys of the West will have more digestible fiber than that grown in lower valleys.

- Leaves are both lower in fiber content and higher in fiber digestibility. Therefore harvesting losses will result in greater RFQ loss than RFV.
- RFQ is reduced by heat damage but RFV is not.

In most instances RFQ and RFV average about the same so RFQ can be substituted for RFV in pricing, contracts, and other uses. However, individual samples may vary significantly. When this occurs, growers should use RFQ. The variables used to calculate RFQ are a better measure of animal performance, as they take into consideration differences in fiber digestibility.

Visual appraisals, guesses, estimates, and book values are inadequate to determine feeding values. To obtain maximum animal performance at lowest feed costs, animal requirements must be met through feed testing and ration balancing.

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