Cornell University
Cooperative Extension

Agronomy Fact Sheet Series Fact Sheet 90

Forage Quality Parameters Explained

Introduction

Some understanding of forage quality parameters for ruminant animals can help agronomists and crop consultants that are working with dairy farms to better manage forage production on the farm. Forage quality is influenced, among others, by plant maturity at the time of harvest, variety selection, and crop species. Forage quality tests should be utilized to quantify and compare individual forage quality components, but results often include many acronyms. The focus of this fact sheet is to help agronomists understand the main forage quality components related to carbohydrates, fat, protein, and mineral content of the forage.

Dry Matter

The first line of a forage quality report is usually the percent dry matter (DM). This is the amount of DM in the forage as it arrived at the laboratory. To be useful for determining actual DM content of a forage on farm, seal the sample and mail it to the laboratory right after it is taken to minimize moisture loss during transport. Forage quality parameters are reported on a DM basis, or per unit weight of dry matter, unless otherwise noted.

Carbohydrates

Carbohydrates include fibrous and non-fibrous carbohydrates. Fibrous carbohydrates (fiber) are compounds that make up cell walls. Fiber enables rigidity in plants, and is a major energy source for livestock, while promoting rumen health and cud chewing. A diet high in fiber decreases overall feed intake because the animal remains full longer. A balance between slowly digested fiber and rapidly digested carbohydrates is necessary.

Fiber can be broken down into cellulose, hemicellulose, and lignin. All three increase with plant maturity because cell walls thicken (Figure 1). Cellulose and hemicellulose are digestible in the rumen. Lignin is an indigestible fiber component, and often binds to cellulose and hemicellulose, blocking digestion. Brown midrib (BMR) varieties have lower lignin content, which increases digestibility.

Two indicators of fiber content are acid detergent fiber (ADF) and neutral detergent fiber (NDF). The names reflect a laboratory procedure: "neutral detergent" is isolated using a neutral wash, as opposed to an acid wash that is used to determine acid detergent fiber.

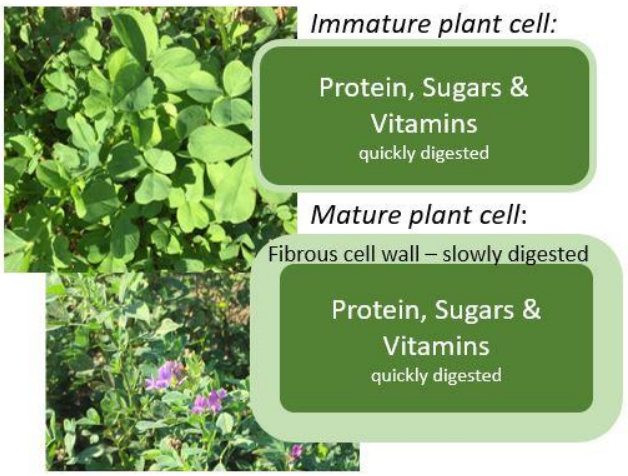

Figure 1: Mature plant cells have thickened cell walls, which increases fiber content, but decreases digestibility.

Acid detergent fiber is the measure of the cellulose and lignin content, which is nearly indigestible. Neutral detergent fiber is a measure of cellulose, hemicellulose, and lignin, and correlates well with animal feed intake. Issues arise if a forage has high levels of either proteins or soil contaminants, because both can falsely inflate NDF estimates, because these contaminants are left behind by the neutral wash. Since NDF is used to determine energy content, falsely inflated NDF leads to underfeeding of animals. If extra steps to remove non-organic contaminants and proteins are taken, it will result in an estimate of "aNDFom," a value that better represents fiber and energy content than NDF. The "a" stands for amylase, an enzyme, and "om" stands for organic matter. Forage aNDFom is lower than NDF, because these contaminants have been removed. These corrections are important if a forage sample is particularly high in protein, or was harvested on sandy soil or during wet field conditions. Neutral detergent fiber digestibility (NDFD) describes the digestible portion of NDF.

When reported as a percentage of NDF, NDFD should be 40-60%, but it can be reported on a dry matter basis as well, resulting in lower values. Undigestible neutral detergent fiber digestibility (uNDFD) describes the un-digestible portion, also as a percentage of NDF or DM. See table 1 for appropriate NDF and NDFD values for hay and corn silage.

Table 1: Appropriate ranges for common New York forages.

Feedstuff	Hay Crop	Corn Silage
NDF	48-55%	38-44%
NDFD (% NDF)	>55%	>52%
Crude protein	15-25%	7-9%
Ash	<9%	<5%

Source: "How to Analyze a Forage Quality Report"

Non-fibrous carbohydrates, or NFC, are carbohydrates that do not make up the cell wall and can be digested quickly. This includes starches, sugars, and some acids. Non-fibrous carbohydrates can be digested in the rumen and used as energy by rumen microbes, or digested in the hindgut. Water soluble sugars (WSC) and ethanol soluble sugars (ESC) are two measures of simple sugar content, which range from 3% to 8% in good quality forage. Starch is found in the grain portion of forage crops and is energy dense. Starch ranges from 30 to 40% in corn silage, but is very low in hay.

Fat

Fats are essential to animal health to absorb some vitamins, provide insulation, protection, and for neural functions. Crude fat (CF) is a measure of all fat molecules, but it can include contamination from plant pigments, esters, and aldehydes. Total fatty acid (TFA) is a measure of fat that does not include these contaminants.

Protein

Crude protein (CP) is the total nitrogen (N) content of a forage, which is slightly higher than total protein because it includes non-protein N. See table 1 for appropriate CP ranges for hay and corn silage. Protein can be divided into subgroups. Soluble protein (SP) is an estimate of true protein and non-protein N that is digested in the rumen, and used by microbes there as a source for N, targeted at 55% of crude protein or less. Rumen degradable protein (RDP) includes soluble protein as well as some other proteins that are partially digested in the rumen. This contrasts with RUP (rumen undegradable protein) that bypasses the rumen. Neutral detergent insoluble crude protein (NDICP) describes RUP that is digested in the hindgut, as protein is in non-ruminant animals. Acid detergent insoluble crude protein (ADICP) is protein that is unavailable for digestion, most likely due to heat damage. On a forage quality report, ADICP is subtracted from CP to find available protein.

Minerals

Ash is the total mineral component in a forage, which includes inorganic compounds in the plant as well as soil contaminants. A high ash content indicates significant contamination by soil, which can inflate NDF. See table 1 for appropriate ash values for hay and corn silage. Mineral nutrients essential for metabolic functions are included in a forage report, including but not limited to Ca, P, Mg, K, Na, Fe, Zn, Cu, Mn, Mo, S, and Cl.

Summary

Carbohydrates, fat, protein, and mineral composition contribute to forage quality. These parameters vary based on crop species, environment, nutrient management, harvest time, and more. Testing forage for key quality parameters aids in creating a balanced ration.

Additional Resource

- Understanding & Significance of Forage Analysis Results: http://dairyone.com/wp-content/uploads/2014/01/Understanding-Significance-of-Forage-Results.pdf
- "How to Analyze a Forage Quality Report" (waiting on a link from Paul)

Disclaimer

This fact sheet reflects the current (and past) authors' best effort to interpret a complex body of scientific research, and to translate this into practical management options. Following the guidance provided in this fact sheet does not assure compliance with any applicable law, rule, regulation or standard, or the achievement of particular discharge levels from agricultural land.

For more information

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2016