Forage Quality: Concepts and Practices

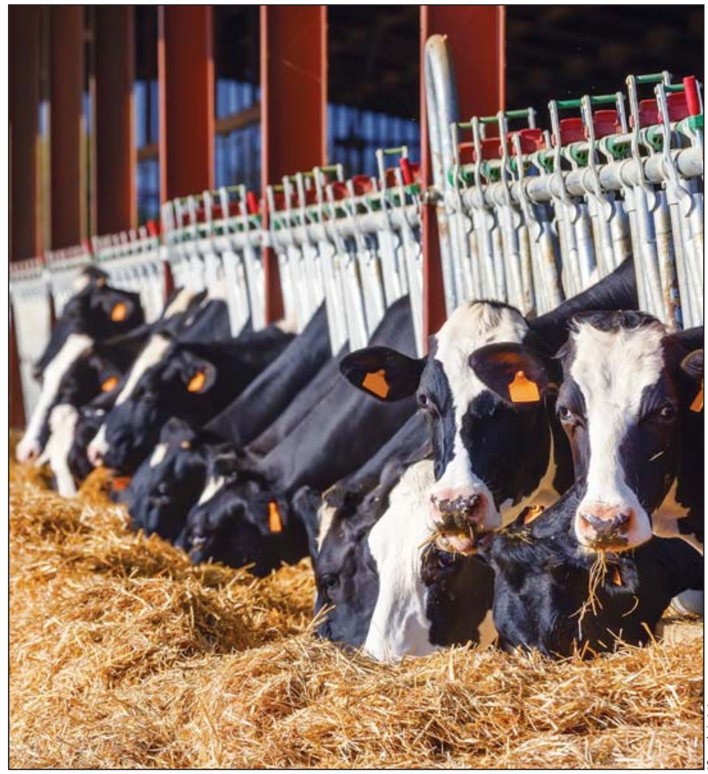
By Miguel Castillo

Forage quality is a determinant of animal performance.
Nutritive value and intake factors determine forage quality.
Forage quality estimates and indices can aid in allocation of forages among different classes of animals.

Forages play a critical role in nutrition of herbivores, and are the foundation of most livestock rations. Nutritional requirements vary among different kinds and classes of grazing animals; thus, what constitutes "high quality" forage for one animal may be "low quality" forage for another. For example, a dry cow will not require the same quality forage as a lactating cow.

Forage quality is then a relative term that is best quantified in terms of animal response (Allen et al., 2011) such as "milk in the bucket", "pounds on the scale", or "calves on the ground." Generally, the higher the quality of the forage, the greater the animal response. While the concept of forage quality is fairly simple and straightforward, in reality it is rather complex.

Laboratory analyses of forages can help to better allocate forages to groups of animals with different nutritional needs and to assess the marketable value of forage crops. Nutritive value analyses (**Figure 1**) that include estimates of digestibility, are useful in providing a first assessment of the relative potential of a forage to impact animal performance. However, animal performance is also affected by other factors, such as palatability, anti-quality constituents, and the amount of forage consumed (intake). Collectively, these factors determine the quality of forage (**Figure 2**).



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Factors That Affect Forage Quality

1. Nutritive Value

The nutritive value of forages is assessed by measuring a) nutrient concentration and b) digestibility, and by studying the nature of the end products of digestion. The three major nutrient sources found in forages are carbohydrates, proteins, and lipids, as described below.

a. Nutrient Concentration

Carbohydrates are the major source of energy for the ruminal microorganisms responsible for forage digestion in the rumen. In reality, we feed the ruminant animal by feeding the rumen microorganisms first. These microorganisms are extremely important for ruminants consuming forages because they convert the carbohydrates in the forage into volatile fatty acids, which are the major energy sources for grazing ruminants. Forage carbohydrates are divided into structural carbohydrates, found in plant cell walls, and nonstructural carbohydrates, which represent cell contents.

Nonstructural carbohydrates: These consist of a group of different types of sugars (e.g., sucrose) and reserve carbohydrates (starch and fructans). Starch is present in all forages, but fructans occur only in cool-season grasses. Starch can be found especially in seeds and roots. Fructans are located in leaves and stems, especially in the lower parts of the plant. As

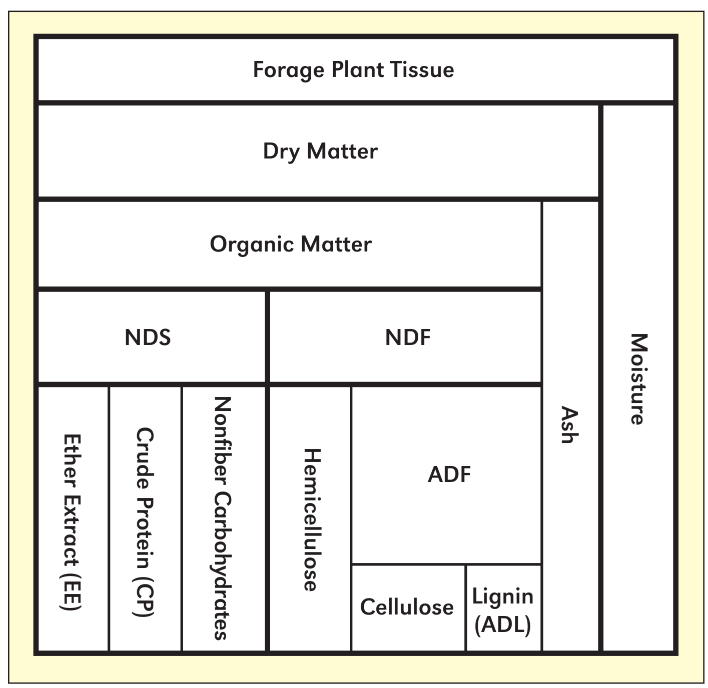

Figure 1. Schematic of laboratory analysis and chemical constituents of forages (adapted from Moore et al., 2007); ADF = acid detergent fiber, ADL = acid detergent lignin; NDF = neutral detergent fiber; NDS = neutral detergent solubles.

Abbreviations and notes: N = nitrogen.

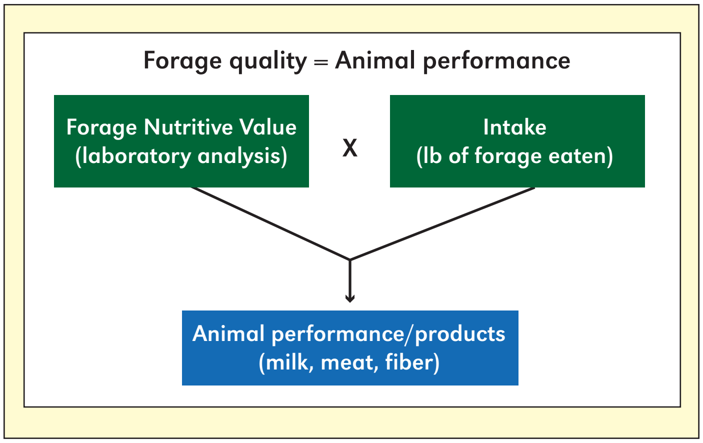

Figure 2. Factors that affect animal performance, or forage quality (adapted from Castillo and Romero, 2016).

long as these carbohydrates are accessible to rumen microbes (through mastication or seed processing), they are rapidly and completely digested.

Structural carbohydrates: The plant cell wall is comprised of cellulose, hemicellulose, lignin, pectin, β-glucans, and polysaccharides. Lignin is a noncarbohydrate component of the cell wall and has a negative impact on digestibility. Detergent fiber analysis divides plant cell walls into neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL). The NDF fraction encompasses cellulose, hemicellulose, and lignin. Pectin and β-glucans are not included in the NDF fraction and they are rapidly and thoroughly digested by microorganisms in ruminants. The ADF fraction encompasses cellulose and lignin; but if not analyzed sequentially after NDF, this fraction may contain some pectin contaminants, especially in legumes. Finally, the ADL fraction represents lignin.

Proteins are polymers formed by amino acids. Protein concentration is typically analyzed as crude protein (CP), which is a measure of the total concentration of N multiplied by 6.25 to estimate total protein concentration in the sample. In forages, nonprotein nitrogen (NPN), which includes free amino acids and ammonium compounds, typically represents 10 to 20% of the total N, but this proportion can increase during wilting and especially if the material is ensiled (Hatfield et al., 2007). The NPN can be turned into bacterial protein in ruminants, but it has little or negligible nutritive value for swine and poultry. Total CP is typically greater in legumes (15 to 25%) compared with grasses (10 to 20%). Nitrogen fertilizer can significantly increase CP content, especially in grasses. Concentrations of CP usually decrease as plants mature due to the accumulation of the fiber fraction (Hatfield et al., 2007).

Lipids are the most energy-rich fraction, typically containing 2.25 times more energy than either carbohydrates or proteins. The most relevant lipids in animal nutrition are fatty acids, triglycerides, and phospholipids. Fatty acids typically constitute 1 to 3% of forage dry matter (DM), with the majority being polyunsaturated (Hatfield et al., 2007). **Table 1** describes the nutritional composition of select forages.

b. Digestibility

Laboratory (in vitro) procedures have been developed to estimate digestibility, which is referred to in the literature as either in vitro DM digestibility (IVDMD) or disappearance.

Table 1. Nutritional composition of select forages[1].

Forage	TDN	Ash	CP	EE	NDF	ADF
	------	------	------	%	------	------
Alfalfa hay[2]	60.0	9.2	19.9	2.9	39.3	31.9
Bermudagrass hay[3]	49.0	8.1	7.8	2.7	73.3	36.8
Corn silage[4]	72.0	3.6	8.7	3.1	46.0	26.6
Fescue hay[5]	44.0	6.8	10.8	4.7	70.0	39.0
Ladino clover hay[6]	60.0	9.4	22.4	2.7	36.0	32.0
Orchardgrass hay[7]	65.0	8.5	12.8	2.9	59.6	33.8
Ryegrass fresh	84.0	-	17.9	4.1	61.0	38.0
Sorghum silage	60.0	5.9	9.4	2.6	60.8	38.8

[1]Values from NRC (2000); TDN = total digestible nutrients; CP = crude protein; EE = ether extract; NDF = neutral detergent fiber; ADF = acid detergent fiber. [2]Sun-cured, early bloom. [3]Coastal, sun-cured, 43-56 day regrowth. [4]Well eared. [5]Kentucky 31. [6]Sun-cured. [7]Sun-cured, early bloom.

Digestibility is always highest in young immature plant tissue and lowest in mature plant tissue. Broadly, DM digestibility is usually lesser in warm-season forages, intermediate to greater in cool-season forages, and greatest in legumes (**Figure 3**). The in vitro disappearance of NDF (IVNDFD) has been identified as a major predictor of animal performance in lactating cattle. A one-unit increase in IVNDFD is associated with 0.37 lb/day increase in DM intake and 0.55 lb/day increase in 4% fat-corrected milk (Oba and Allen, 1999). The response is especially noticeable with more productive cows. Thus forages with greater IVNDFD should be allocated to the most productive animals.

2. Voluntary Intake

The amount of forage DM that animals consume when they have an unrestricted supply is considered voluntary intake. Animal performance depends on the daily intake of DM multiplied by its digestibility. Intake is the main determinant of animal performance, followed by digestibility. Animals consuming forages with greater fiber concentrations may not meet their energy requirements due to rumen fill, as shown in **Figure 4**. However, ruminants will regulate intake to meet their energy requirements when rumen fill is not a limiting factor.

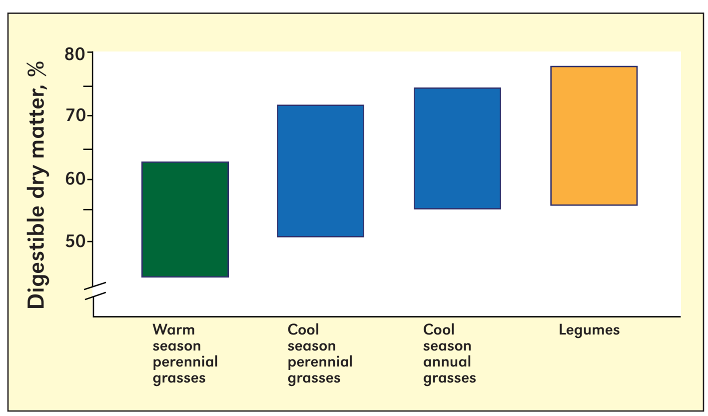

Figure 3. Digestibility ranges of major forage types (adapted from Ball et al., 2015). While the overall trend increases, ranges are wide and overlap among categories.

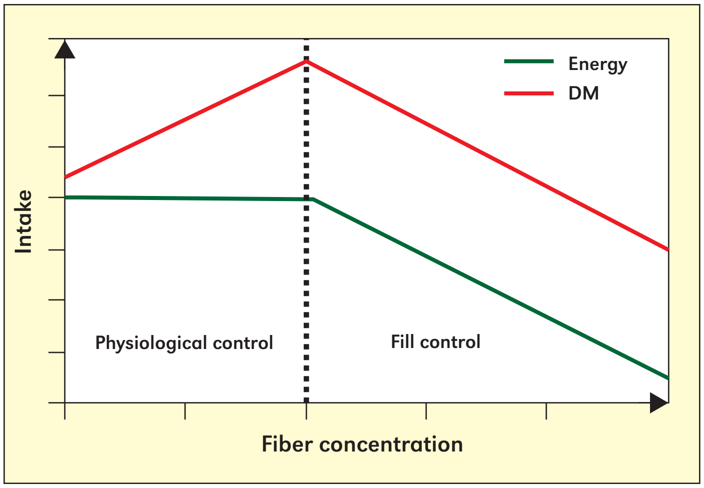

Figure 4. Relationship between fiber concentration and intake (adapted from Collins and Fritz, 2003). The first half of the figure shows that dry matter (DM) intake increases as fiber concentration in the forage increases. Energy intake remains constant, however, as a result of physiological mechanisms regulating energy metabolism (physiological control). Once ruminal fill reaches maximum capacity, DM and energy intake decrease as forage fiber concentration increases (fill control). During this stage, energy requirements are likely not being met due to high fiber concentration of the mature forage.

Unfortunately, intake is the forage attribute most difficult to measure because actual intake is a function of forage characteristics (i.e., palatability, physical properties, and nutrient availability), animal characteristics (i.e., capacity, appetite), and management (i.e., feeding, stress). Nevertheless, NDF concentration and IVNDFD can be used to predict intake.

3. Palatability

Palatability is the characteristic of a feed affecting its acceptability by animals. When given free-choice access to forages, animals can select one forage over another or parts of the same forage based on plant characteristics such as smell, texture, moisture content, height and density of sward, infestation, color, and taste. Thus palatability can also affect the rate at which animals consume forages. High quality forages are generally very palatable.

4. Anti-quality Factors

Several compounds can be present in forages that affect animal performance, cause sickness, or possibly cause animal death. These include such compounds as alkaloids, tannins, and phytoestrogens in many legumes, nitrates in many grasses, and cyanoglycosides in white clover and sorghum, as well as mycotoxins in many forages. The presence and concentrations of these compounds vary among plant species (including weeds) and are often influenced by environmental factors and animal sensitivity. For example, elevated concentrations of tannins can reduce intake and rumen digestibility. But in relatively reduced concentrations, condensed tannins can be beneficial by increasing bypass protein. In general, forages of desirable quality should not have these compounds. Or if these compounds are present, they should be at reduced concentrations that do not negatively affect animal responses.

Predicting Forage Quality

Two systems have been developed to express forage quality in terms of an index that combines both intake and digestibility. The relative feed value (RFV) index was developed by the American Forage and Grassland Council (Rohweder et al., 1978), and the relative forage quality (RFQ) system was developed by Moore and Undersander (2002). The RFQ system was developed to overcome the limitations of RFV, particularly its limited ability to compare among forage families and its inability to update prediction equations. This was achieved by introducing IVNDFD in the calculations and using total digestible nutrient (TDN) equations.

The RFQ is especially advantageous over the RFV index when evaluating grasses and grass-and-legume mixtures compared to legumes only. In both systems, a 100 value represents roughly a full-bloom alfalfa. The greater the index, the better is the forage quality. For further information on these indices see the source article (Romero et al., 2014).

Summary

Forage quality is a broad term that includes not only nutritive value, but also forage intake and anti-quality factors. Forage quality can be expressed as an index, such as RFV and RFQ. These indices can be used to appraise the potential of forages to impact animal performance. A better prediction of forage quality can be achieved by combining measurements of nutrient concentrations and ruminal in vitro dry matter disappearance. This information can help in the allocation of forages based on quality and nutritional needs and performance potential of animals, such as lactating cows and growing steers. BC

Acknowledgement

This article has been adapted from the NCSU Cooperative Extension publication available at: http://www.forages.ncsu.edu/assets/ag792.pdf

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