Forage Nutritive Value

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Forage nutritive value is generally analyzed by relating the attributes of nutritive value to plant phenology in order to predict the decline of these attributes with plant age. A more functional analysis is based on the assumption that above ground plant mass (W) is composed of two compartments: (i) the metabolic compartment (Wm) 18 associated with plant growth processes scaling with leaf area and having high N concentration (%N) and digestibility (%D); and (ii) the structural compartment (Ws) associated with the architectural plant development scaling with plant height and thickness and having low %N and %D. If we postulate that Wm is allometrically related to W, the ontogenetic decline of both %N and %D as plant gets bigger and forage mass increases can be explained and described. The theoretical framework developed in this review allows the expression of a mechanistic link between the increase in plant size and the decrease of both forage crude protein concentration and digestibility linking forage production and forage nutritive value dynamics within the same functional approach for a better understanding of genotype-environment-management interactions.

Keywords: Forage digestibility ; Crude protein content ; Leaf:Stem ratio ; Production quality trade-off

1. Introduction

The nutritive value of forage for herbivores has been for a long time determined by the concentration in protein and, hence in nitrogen (N), the concentration in different minerals (P, K, Ca, Mg, and oligo-elements), and the in vivo dry matter (DM) digestibility. Forage DM digestibility, the proportion of ingested DM being metabolized by ruminant animals has been related to different components of plant tissue composition such as Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF); the NDF concentration represents an estimate of cell wall content while the ADF concentration is an estimate of the more lignified cell wall content. Forage nutritive value is generally analyzed by relating the attributes of nutritive value to plant phenology, in order to predict the decline of these attributes with plant age. A more functional approach, initially developed for the analysis of N concentration dynamic analysis [1,2] and extended for digestibility for this review, is based on the assumption that above-ground plant mass (W) is composed of two compartments: (i) the metabolic compartment (Wm), associated with plant growth process scaling with leaf area, having a high N concentration (%N), and a high Digestibility (%D); (ii) the structural compartment (Ws) associated with architectural plant development, scaling with plant height and thickness and having low %N and %D. With the postulate that Wm is allometrically related to W ($Wm = c \times W^{\alpha}$ with $\alpha < 1$), the ontogenetic decline of both %N and %D as the plant gets bigger and forage mass increases can be explained, and the purely empirical statistical approach of forage quality based on plant phenology can be replaced by a more mechanistic and comprehensive analysis linking forage production and forage quality dynamics within the same functional approach for a better understanding of genotype-environment-management interactions.

2. Relationship between Digestibility and Crude Protein of Forage Crop

This review provides several convergent pieces of evidence demonstrating that the general links established between digestibility and crude protein of forage crop and the plant phenology were due to correlations with time, but were not a causal relationship. As a result, the prediction of forage quality through observation of plant phenology stages is highly uncertain in the context of contrasting growing conditions related to cultivars, seasons, climate, and crop N nutrition. The theoretical framework developed in this review allows the expression of a mechanistic link between an increase in plant size and a decrease of both forage crude protein concentration and digestibility. As the plant gets bigger, its structural tissues that have a low N concentration and low digestibility increase proportionally more rapidly than its metabolic tissues that have a high N concentration and high digestibility, which leads then to a parallel decrease of crude protein concentration and forage digestibility as crop mass increases. The Leaf/Stem ratio provides a relevant approximation of the proportion of structural and metabolic tissues for species with a very low proportion of structural tissues in their leaves such as alfalfa or timothy, but not for species with leaves that have more abundant vascular bundles and midrib tissues.

Stem height also appears to be an important parameter for explaining the decrease in forage quality as forage mass increases. As stem height increases, the lignification of cell walls at the base of the stem increases, which leads then to a decline in the digestibility of stem tissues.

The theoretical framework presented in this review has been based on general allometry relationships in plant architecture observed mainly for perennial grasses and legumes, and illustrated by results obtained in a few numbers of species, mainly timothy and alfalfa. The degree of genericity of this framework to a larger range of species, including annual forage, can be questioned. However, the wide and successful use of these allometry relationships across a large range of annual crop species for analyzing crop N nutrition and crop N concentration dynamics in relation to crop mass accumulation suggests high genericity. The use of this framework as a tool for analyzing these genetic or environmental variations should then help in a better understanding of Genotype-Environment-Management interactions on the trade-off between forage production and forage quality.
