

### 3.3. CELL WALLS AND CELL SOLUBLES

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#### INTRODUCTION

Animal nutritionists have attempted to describe feed quality by laboratory analyses at least since the 'Proximate Analysis' was developed in Germany in the previous century. Quite obviously, these older methods are replaced or supplemented by newer approaches. Since the last few decades the measurement of crude fibre and so called Nitrogen Free Extract ("Soluble carbohydrates") is replaced with the use of cell walls and cell solubles as an indicator of digestibility (quality). Because these terms are frequently used in this book, we will briefly explain the principles and concepts behind this analysis.

#### THE PROXIMATE ANALYSIS

Laboratory values are not the same as those used by the farmers, but fortunately they appear to overlap at least to some extent (Table 1). Since long, nutritional characteristics of feeds have been expressed in chemical terms. One of the oldest systems of analysis is the Proximate Analysis, also called Weende system. It describes the feeds in terms of crude protein (CP),

crude fibre (CF), crude fat or ether extract (EE), ash, and nitrogen free extractive (NFE). The components of these different fractions are shown in Table 2. It was soon recognised that the digestibility of feeds, and hence their nutritive value, was adversely affected by CF content, while high protein feeds were more digestible. Based on these observations, the CF contents have long been useful as an indicator of feed quality.

**Table 1. Likely similarities between farmer perception of straw quality and laboratory evaluation**

<b>Straw characteristic desired by farmers</b>	<b>Correlation found in laboratory evaluation</b>
Leafiness	Leaf digestibility > stem digestibility (for most crops)
Sweetness	More cell solubles (NDS) in sweet varieties
Stay green	More cell solubles in varieties that stay green longer
Texture	High silica in varieties with coarse texture
Colour	Spoilage/pigmented varieties

Note: This list is prepared on the basis of discussions in the National Seminar on variability in quality and quantity of straws (Joshi *et al.*, 1994)

The proximate analysis is still used in description of animal feeds, but its limitations in predicting the digestibility of fibrous feedstuffs are becoming increasingly obvious. The laboratory procedure for CF determination involves successive use of mild acid and alkali, which tends to dissolve part of the (hemi)cellulose and lignin. The problem is that in reality, these latter components are part of the plant cell wall, i.e. the fraction that is resistant to the digestion in the rumen. Thus due to analytical problems, part of the

fibre that is variably available to the animal is estimated as completely digested, thus overestimating the nutritive value of the feed. This is because the NFE fraction which is meant to represent the soluble nutrients minus the proteins, is calculated by difference.

**Table 2. Components of different fractions in the Proximate Analysis of foods.**

<b>Fraction</b>	<b>Components</b>
Moisture	Water (and volatile acids and bases if present)
Ash *)	Essential and non-essential
Crude protein	Proteins, amino acids, amines, nitrates, nitrogenous glycosides, glycolipids, B-vitamins, nucleic acids
Ether-extract **)	Fats, oils, waxes, organic acids, pigments, sterols, vitamins A, D, E, K
Crude fibre	Cellulose, hemicelluloses, lignin
Nitrogen-free extractives	Cellulose, hemicellulose, lignin, sugars, fructans, starch, pectins, organic acids, resins, tannins, pigments, water-soluble vitamins

Source: Adapted from Mc. Donald *et al.*, 1981

Notes: \*) Particularly in rice straw and sugarcane tops, the silica content is very high.

\*\*\*) In fibrous feeds, the ether extract (EE) is generally very low around 0.5-1.5% of the dry matter. It contains a high proportion of the non-fats; it is therefore not very useful to determine EE or digestible EE in fibrous crop residues.

Analytical errors or assumptions in fibre determination can cause marked errors in its estimations. As the nutritive value of grasses, straws and stovers for ruminants depends on the digestibility of the fibre, a more precise determination of this fraction is important particularly in farming systems utilizing fibrous feeds as a major feed resource.

## THE "VAN SOEST" FORAGE FIBRE ANALYSIS

A newer, and more fundamental approach to feed analysis was developed during the late 60's and early 70's in the U.S.A. by a group of workers headed by P. Van Soest. Their approach partitions the feed organic matter into cell wall and cell solubles, the latter is also called cell contents. This division was considered more logical in view of the chemical uniformity of the fibre fraction which was overlooked in the older system. Furthermore, these two fractions can also be classified as having low and high digestibility in the rumen. The cell walls are variably, but generally not easily and rapidly digestible, whereas the cell contents can be assumed to be completely digestible.

The significance of this distinction for those involved in feeding of fibrous feeds (i.e. straws), lies in the fact that the cell wall is the part that ultimately remains in the straw. When harvest approaches, i.e. when grainfill starts, the soluble cell contents are transported (translocated) to the grain, whereas the remaining cell walls mature and thicken into an even less digestible fraction (Table 3). One can note here that:

*A failed harvest implies that the ratio of cell solubles/cell walls increases. This is to the benefit of straw quality: more solubles remain and the cell wall may be less mature.*

There are more factors, however, like duration of the crop, light, temperature, rainfall, use of fertilizers which influence the formation and /or utilization of the cell solubles and therefore the digestibility of the

straws/stovers (#4.5.).

In chemical terms, the cell wall fraction consists of the structural components of the cell, i.e. cellulose, hemicellulose and lignin. In theory, the first two of these are potentially (100%) available through ruminal digestion, because rumen microorganisms provide the enzymes cellulase and hemicellulase.

**Table 3. Effect of stage of maturity of crop on composition and digestibility of finger millet stovers \*)**

Stage of maturity	Characteristic *)			
	NDF(%) cell wall	NDS(%) cell solubles	OMD(%)	NDFD(%)
Flowering	59.0	30.2	74.0	60.7
Dough	59.1	30.6	69.4	53.6
Physiological maturity (PM)	66.5	22.5	60.9	47.8
Ten days after PM	68.5	21.7	56.6	42.8
After 150 of storage	70.5	17.5	48.7	36.0

Source: Subba Rao *et al.*, 1993

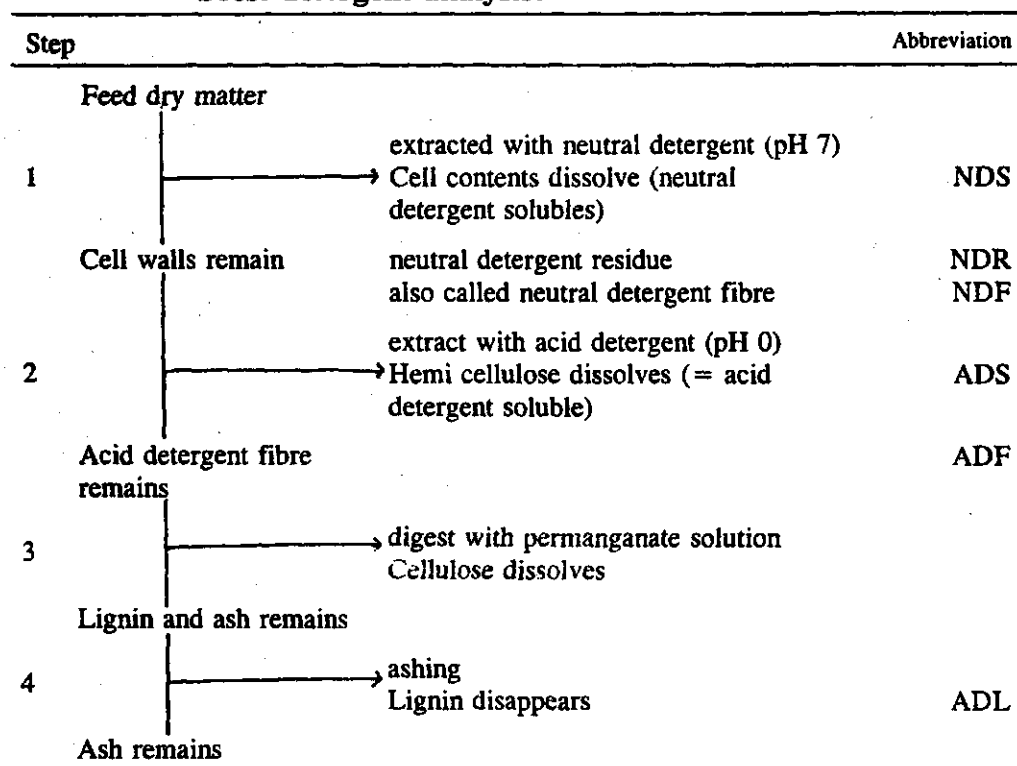
- \*) NDF = Neutral Detergent Fibre  
 NDS = Neutral Detergent Solubles  
 OMD = Organic Matter Digestibility  
 NDFD = NDF Digestibility

The actual degradation of these two energy yielding fractions is however limited on account of the lignin associated with the cellulose and hemicellulose, and also because of the relatively short time that the feed

remains in the rumen. Whereas lignin is often blamed for the low digestibility of the straws and stovers, its role is rather limited. The first cause for the inferior nutritive value of crop residues is the low content of cell solubles, i.e. the feed component that makes young grass so valuable is lacking in straw.

The detergent analysis is so named because it uses detergent solvents of different pH, represented schematically in Figure 1.

**Figure 1. The process of fibre fractionation according to the Van Soest detergent analysis.**



(Source: Ranjhan, S.K., 1993)

The cell wall content is determined in the laboratory by boiling the dry ground feed with a solution of neutral detergents with a pH of 7.0. This solution dissolves all the soluble nutrients from the plant material leaving behind residue of plant cell walls. Due to the use of the neutral detergent solution in the analysis the residue (cell walls) is often referred to as Neutral Detergent Fibre (NDF) and the cell solubles as Neutral Detergent Solubles (NDS). The cell wall fraction (NDF) can further be treated with acid detergent solution to dissolve hemicellulose leaving a residue called Acid Detergent Fibre (ADF) which is made up of the cellulose, lignin and ash. The ADF is separated into its components by using sulphuric acid or potassium permanganate. Thus a complete description of the plant cell wall is obtained through the detergent analysis system. In most cases, an analysis for NDF is sufficient for characterization of the feed as it basically represents the fibre fraction.

The NDS fraction consists of the soluble nutrients in the cell i.e. amino acids, peptides, sugars and minerals. This is estimated indirectly by subtracting %ash and %NDF from 100. i.e.

$$NDS = 100 - (\%ASH) - (\%NDF)$$

The NDS fraction is almost completely (>90%) available to the animal.

The NDF content is generally expressed as %DM (dry matter) but when expressed on the organic matter (OM) basis it facilitates the calculation of organic matter digestibility (OMD). Expression of these values on OM basis also increases the precision of comparing feeds with different ash contents. Analysis of the feed organic matter for NDF content and digestibility of NDF by a suitable technique can be used to estimate the OMD by the

following equation:

$$\%OMD = (\%NDF) * (NDF \text{ digestibility}) + (\%NDS) * (NDS \text{ digestibility})$$

For example, a straw sample containing 70% NDF (OM basis) with 45% digestibility of NDF will have an OMD of

$$\begin{aligned}\%OMD &= (70)*(0.45) + (30)*(0.9) \\ &= 31.5 + 27 = 58.5\end{aligned}$$

The laboratory technique for determination of NDF is simple, quick, reproducible and can be used to describe the nutritional quality of the feed along with other nutrients like CP. Comparison between the detergent analysis system (Figure 1) and the Proximate analysis (Table 2) shows the inaccuracy of the previously used CF analysis as a measure for fibre content of the plant.

## CONCLUSION

The use of crude fibre has long served as an indicator of digestibility and hence of nutritive value of animal feeds. However, the inaccuracy of the chemical approach has led to the development of a more reliable, simpler and biologically more acceptable method to distinguish between cell walls (NDF) and cell solubles (NDS). The understanding of these principles helps for example, to see why - within species - straws of mature and longer duration crops tend to have a lower nutritive value than a failed grain crop or crops of shorter duration. Together with other laboratory measurements like ash, protein content and (rate of) degradation, the new approach will function as a useful parameter of nutritive value for both agronomists and animal nutritionists.



**SUGGESTED READING**

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