Lecture 2

CHEMICAL COMPOSITION OF FORAGES

Herbages contain a variety of chemical constituents which serve as nutrients for herbivores. Some nutrients are sources while others satisfy specific requirements in the body of the animal.

The chemical composition of the dry matter of pasture grass is very variable for instance the crude protein (CP) content may range from as little as 30g/kg (i.e. 3%) in very mature herbages to over 300g/kg (or 30%) in young heavily fertilized grass.

The fibre content is inversely related to the crude protein content, and the acid detergent fibre may range from 200 to over 450g/kg (20-45%) in very mature tropical grasses.

The moisture content is of particular importance when a crop is being harvested for conservation. It is very high in very young material, always in the range of 750 – 780g/kg (75-78%), and falls as the forage matures to about 650g/kg. Weather condition is a major determinant of moisture content.

According to Van Soest (1967) the chemical component of forages can be broadly divided into cell wall constituents (CWC) and cell contents (CC) or into digestible and indigestible or poorly digestible fractions.

The CC is generally highly digestible and the CWC (commonly referred to as fibre) is either indigestible or poorly digestible. The CC is soluble in neutral detergent while the CWC are only partially soluble in acid detergent. Associations of soluble carbohydrates, starch, organic acids, cellulose and hemicelluloses together with lipids (fats) contribute to the energy content of forages. Proteins, vitamins and minerals provide essential components of animal diet and are required in an appropriate balance if animals are to perform optimally. Forage plants may also contain anti-quality factors such as tannins, or even poisonous constituents which may affect animal performance.

Proteins

Protein is often the constituent which most limits the performance on animals on pasture. Crude protein (CP) comprises natural proteins (i.e. part of the plant tissue constituents) as well as non-protein constituents (NPN). CP is estimated by multiplying the nitrogen (N) content of the forage by a factor of 6.25.

This provides only a gross estimate which does not distinguish between the protein needs of the micro-flora in the rumen and protein available for absorption in the lower digestive tract, or the quality or origin of the protein.

The protein requirement varies according to species of animals, age, and the physiological functions of the animal (e.g. lactating, young, pregnant etc). Generally, the minimum protein requirement of ruminants is between 7 and 8 % but high producing animals require levels approaching 13% to 14% and where the protein levels is lower than the minimum requirement, protein needs to be supplemented.

The CP contents vary widely among forage plants but in all species and in all seasons, it declines with increasing age of the forage. N-fertilizer application will normally increase the CP concentration in forages, but much of this may be in the form of NPN which is of little value to the animal and may in fact be harmful and cause nitrate poisoning. Animals should therefore be kept off N-fertilized areas for about three weeks following top dressing.

Minerals

A comprehensive mineral need of livestock is given in tables presented by National Research Council (1984, 1985).

Phosphorus is generally in short supply in most of the tropics for most of the year. Supplementation with P is therefore often recommended throughout the year on many types of pasture. When selective grazing is allowed to fully operate as in a continuous grazing system, P intake is never constrained as animals select the young shoots of plants which contain higher proportion of P than other plant parts.

Other important minerals for good performance of livestock are Na, Ca, K, Mg, S, Zn, Co, Cu, Mn, Mo, I, Se. The concentration of the minerals in forages is determined to a large extent by the maturity of the material. Mineral concentration declines with age and is also influenced by soil type, soil nutrient levels and seasonal conditions.

Structural Constituents (Cell wall or fibre)

The structural constituents of plant materials include polysaccharides, lignin and some proteins. The constituents can be divided into matrix polysaccharides (including hemicellulose and pectin) and fibre polysaccharides (cellulose, lignin, and proteins). All these components have been termed fibre and may be incompletely or variably digested by the animal.

The stems of most forage have larger proportion of polysaccharides and lignin than the leaves. This proportion increases with maturity in both tropical and temperate forage species. Tropical species appear to have greater cellulose content and a higher hemicellulose: cellulose ratio than temperate species. During digestion, once lignin has been removed, the polysaccharides of the cell wall become more readily digestible.

The lignin in plant fibre however resists microbial enzyme attack in the rumen and thus reduces digestibility through its linkage with specific points on the polysaccharide chains and it prevents physical attachment of rumen bacteria to plant cell walls.

Vitamins

These are another group of essential chemical constituents, but are required only in small amounts. The most important of them is vitamin A which is usually well provided for in green forages and well cured leafy hay.

Anti-quality and toxic substances

The final group of chemicals that are found in forages are toxic substances. Certain legumes (e.g. Lucerne and clover) contain substances which cause bloats. Others contain tannins which reduce the digestibility if forage.

Palatability and Acceptability

Palatability is broadly defined as the relish with which a particular specie or plant part is consumed by the animal. It can also be explained as those factors of the feed itself which determine the absolute attractiveness of the feed to the animal.

Acceptability on the other hand can be defined as the attractiveness of the feed to the animal as determined by the factors of the forage and the environment. It is therefore a relative term and depends on the circumstance under which the forage is presented to the animal.

The distinction between these two terms is not always clear, but the following example will be used to explain it:

A mature grass in the dry season may be both unpalatable and unacceptable but if urea lick is provided to animals while feeding on it, the material becomes acceptable to livestock even though its chemical and physical properties are not altered and so neither is its palatability. This apparently arises from the improved digestibility of the material when fed together with a nitrogen source.

Another example is that of the avoidance by animals of forage in close proximity to dung or urine patches. This material is unacceptable in-situ but, if removed from the soiled area, it may readily be acceptable even though its palatability has not changed.

Therefore potentially palatable feed can be unacceptable, and unpalatable feed can be made acceptable.

Another example therefore is the use of molasses to improve the acceptability of low quality unpalatable hay or soil pasture.

Acceptability has generally been found to be positively correlated with the concentration of protein, energy, minerals, ether extract and water content and negatively correlated with fibre and lignin contents of the forage. Acceptability is also strongly influenced by the physical properties and structure of the plant. In grasses for example, selection by both cattle and sheep has been found to be negatively correlated with leaf strength.

Plant structure may influence acceptability by affecting the accessibility of leaf to the grazing animal.

Thorns and spines may reduce the acceptability of certain woody browse species below levels expected from their leaf nutrient content.

Acceptability may also be reduced by the presence of awns, hairs or stickiness and by the coarseness or harshness of the leaves.

Plant secondary metabolites, such as tannins and alkaloids are common amongst woody browse species and may significantly depress their acceptability to browsers such as goats.

Apart from characteristics of the plant species itself, acceptability is also strongly influenced by the situation in the plant grows. Neighbouring plants of other species may modify a plant's acceptability by discouraging animals from grazing in their vicinity because of their odour (which may be repulsive) or by physically reducing access to the plant (For instance palatable plant in the midst of plants with very sharp and hard thorns that can injure the animal).

Generally, acceptability is influenced by the relative abundance and associated preference of other species growing in the same area. Thus, the acceptability of species may increase, for example, as the relative availability of other more acceptable species decline during grazing.

Intake

Intake is the most important factor influencing the feeding value of forages and therefore in determining the performance of grazing livestock. Although digestibility has a very close linkage with intake, intake is more than twice as important as digestibility in determining animal performance. Therefore an understanding of the factors which affect intake on pastures is extremely important and so some knowledge of the digestion process in ruminants is necessary.

The rate of food particle disintegration and its passage out of the rumen regulates intake and largely determines the difference in intake between different species of forages. The rate of disintegration in the rumen is closely related to the abundance and nature of cell wall constituents in forage since these constituents depress fermentation and outflow. The greater the proportion of cell wall constituents, the slower are these two processes and the slower the rate of intake.

It can therefore be generally stated that cell wall constituents (CWC) have a greater impact on intake by livestock on pasture and other roughages than those digestibility. The rate of cell wall fermentation generally imposes little limitation on intake at digestibility about 70% and cell wall contents of below 35%. In forages with these characteristics intake is limited rather by poor availability of forage, as well as by palatability, moisture content, grazing management and factors such as excretal contamination of these forage. These factors are important in management decisions, since they can greatly influence animal performance on high quality pastures.

Voluntary intake (VI) (or *ad lib*) of forage

The *ad lib* intake of animal when offered *in excess of a single feed* or forage defines voluntary intake. This is one of the measures used to estimate forage quality. Voluntary intake is not the same as palatability although palatability has an influence on it. Voluntary intake is mainly controlled by involuntary physiological reflexes within the animal rather than its liking for the feed or the forage. Intake in ruminant depends on the capacity of their digestive tracts, especially the rumen.

The animal eats until certain degree of fill is achieved. The level of fill is influenced by digestion and the movement of food residues through the digestive tract. The more rapidly a feed is digested and pass through the animal, the greater the potential for a high intake.

The anatomical studies of forage plants can shed some light on the differences in voluntary intake between forage types. Legumes have less cell wall than grasses and their fibre retention time in the rumen is shorter, contributing to the often observed to the greater intake of legumes than grasses. The sclerenchyma tissue above and below the vascular bundles of many grasses facilities a strong attachment of the cuticle and epidermis to the interior tissues, making grasses more resistant to physical digestion mechanisms. Ruminants are able to eat greater amount of highly digestible forages because they occupy less volume, they are in the rumen for a shorter time and there is less indigestible residues which has to be passed down to the hindgut.

In forages of high digestibility, intake is limited by metabolism factors (blood concentrations of glucose, organic acids (etc) rather than by rumen fill).

Digestibility

This is estimated as the differences between the amount of feed ingested and excreted. Digestibility is one of the major factors which influence animal performance. It is usually positively related to the concentration of nutrients in the forage and to intake. This is because the higher the quantity of nutrients in the feed, the more easily it could be digested.

Various methods have been developed to estimate digestibility.

i. Conventional digestibility trials are undertaken using animals under controlled conditions. Such trials produce *in vivo* (in the body) estimates of digestibility. This procedure is costly and time consuming for large-scale routine analysis of forage samples and does not provide data against which other procedures can be calibrated.

ii. The nylon bag technique (*in sacco*) involves suspension of dry sample of forage enclosed in bags made of indigestible material within the rumen of a rumen-fistulated animal. The bag is removed after a specified period and the loss of dry matter from the bag determined.

This allows for the estimation of both the rate of fermentation and amount of fermentation which has taken place.

The method is however, difficult to standardize because of variations in the pore sizes of the materials used to make the bags and because results are partially dependent on the diet fed to the animals during incubation of samples.

iii. The *in vitro* method of estimating digestibility is the most commonly used worldwide for routine analysis of large numbers of forage samples.

The method attempts to simulate *in vivo* digestion in the laboratory.

The most commonly used *in vitro* method is that of Tilley and Terry (1963), which simulates digestion in both the rumen and the lower gut of ruminants.

It has provided correction with *in vivo* digestibility of between 0.79 and 0.97. The equation below relates *in vivo* and *in vitro* digestibility methods

$$Y=16.4205+0.7892x$$ –Barnes (1973).

Where Y= *in vivo* digestibility value and

X= *in vitro* digestibility value

In the absence of *in vitro* digestibility data one can fall back on TDN (Total digestible nutrients) values where available. These values are often well corrected with *in vivo* and *in vitro* digestibility.

iv. Another technique that has been used with reasonable success is based on cell walls or fibre content of the forage.

Digestibility is negatively related to cell wall (fibre) content especially lignin content.

In the Van Soest analysis (Van Soest, 1982), the indigestible residue of the cell wall component, which is made up partially of lignin, is effectively isolated.

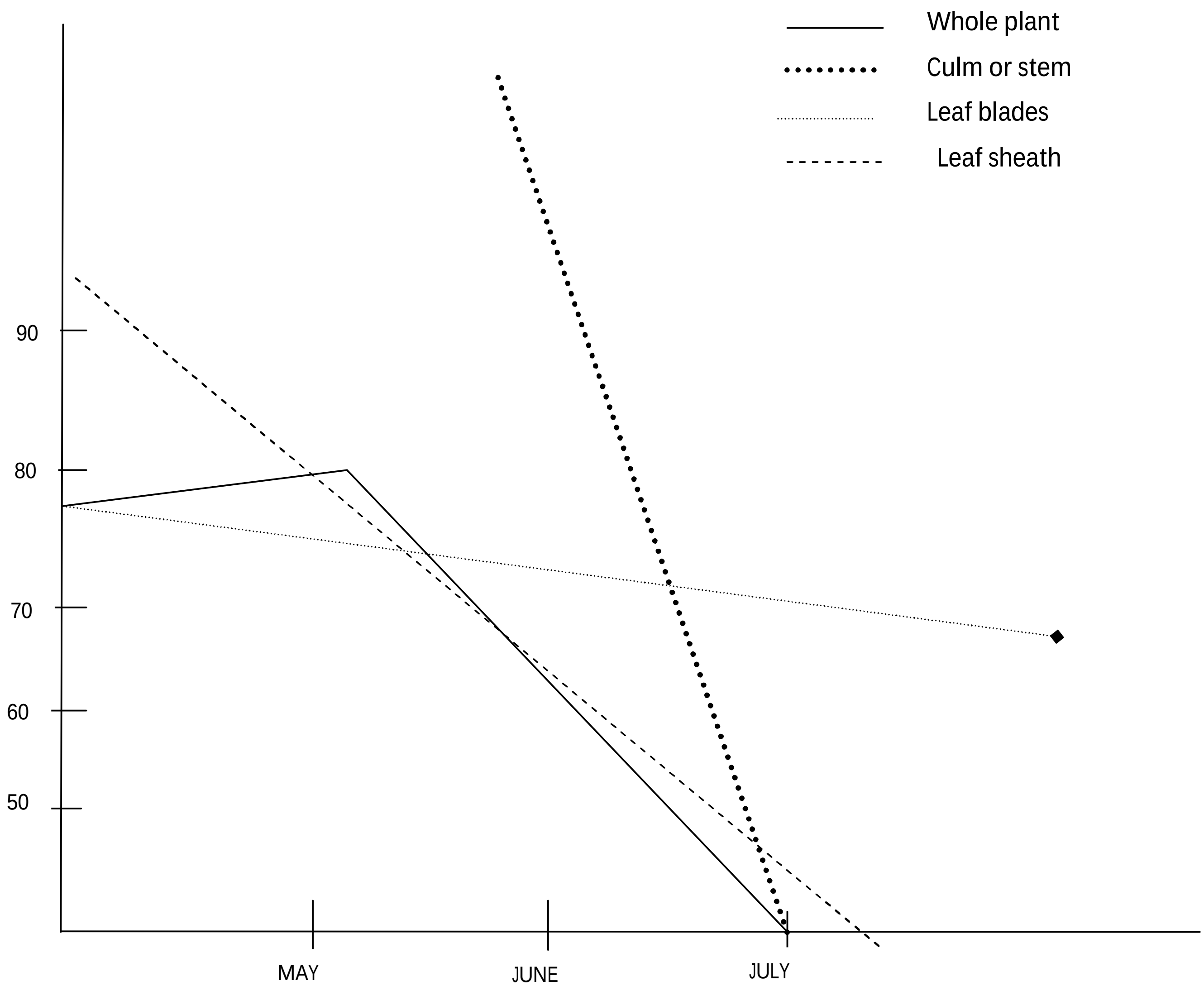
This fraction is referred to as acid detergent fibre which provides the best chemical estimate of digestibility (Rohweder *et al,* 1978).

Factors affecting digestibility of forages

Digestibility is affected directly, by a number of factors and indirectly by grazing management. Typically, the digestibility of tropical and sub-tropical grasses is lower than those of legumes, and temperate grasses. Some of the reasons for this include:

1. Tropical and sub-tropical grasses have higher cell wall content than do grasses of temperate areas and the digestibility of their cell wall material (fibre) is lower than that of temperate grasses. This lower digestibility is due to peculiar structural characteristics such as greater lignifications and lower ratio of mesophyll to parenchyma and bundle sheath material.

2. Tropical and sub-tropical species also have a lower leaf to stem ratio than temperate species. The importance of this is that stem material is typically less digestible than leaf material and its digestibility declines more rapidly with age than that of leaf material as illustrated below.



The in-vitro digestibility of the dry material of the whole plant, leaf sheath, leaf blade, and culm of the early season growth of tropical plant species. Numbers in bracket indicate the percentage culm in the whole plant (from Terry and Tilley, 1964).

3. Plant age is an important factor affecting digestibility although, its influence varies across species, between primary growth and regrowth, and with season.

4. High temperatures result in low digestibility. This may partly explain why tropical and sub-tropical are less digestible than temperate species.

Fertilizer levels also influence digestibility through their influence on growth rate and stage of maturity of the material.

FACTORS AFFECTING CHEMICAL COMPOSITION OF FORAGES

1. Stage of growth

This is the most important factor affecting the composition and nutritive value of forages. As plants grow there is need for fibrous tissues and therefore the main structural carbohydrates (cellulose and hemicellulose) and lignin increase. As the plant ages, the concentration of protein decreases and the fibre content increases. There is therefore a reciprocal relationship between the protein and fibre content in given species.

2. Species
3. Soils and fertilizer treatments
4. Grazing system employed
5. Climatic condition and season

The nutritive value of a pasture is basically a function of the species in the pasture and the stage of growth, but may be modified by climatic factors during growth, soil factors which affect nitrogen and other mineral status, and management factors which affect pasture re-growth rate, sward structure and botanical composition.

Species factor

Tropical grasses: The nutritive value of pasture species even at similar stage of growth varies widely both in DMD and Voluntary Intake. Minson and McLeod (1970) showed that tropical grasses were, on the average 13% lower in DMD than temperate species. Most samples of temperate grasses had digestibility above 65% but few tropical grass samples were in that category. Minson and Mcleod (1970) suggested that the lower DMD values of tropical grasses may in part be due to higher growing temperatures but data obtained from studies that followed by Reid *et al*. (1973) showed that selected or improved species of tropical grasses such as *Brachiaria, Chloris, Setaria* and *Panicum* had DMD values that are comparable to those of similarly managed temperate species.