

COURSE CODE:	PRM 502
COURSE TITLE:	Forage quality and conservation
NUMBER OF UNITS:	2 Units
COURSE DURATION:	Two hours per week

COURSE DETAILS:

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COURSE CONTENT:

Grasses as feed for ruminants, growth pattern, plant parts of grasses and effects on quality. Definition of nutritive values of feed. Chemical composition of forages (proteins, minerals, structural constituents, vitamins, anti-quality and toxic substances) their availability to animals and factors affecting them. Palatability and acceptability of forages (with examples) and factors affecting them. Intake and voluntary intake of tropical forages and factors affecting them. Digestibility. Factors affecting digestibility of tropical forages. Anti-nutritional factors in forages and their effects on animals. Mineral imbalance in forages and corrective measures. Different methods of forage conservation: hay, silage, haylage, use of crop residues in animal feeding etc. Storing and feeding conserved feeds. Feeding value of conserved forages. Health hazards associated with conserved forage.

COURSE REQUIREMENTS:

This is a compulsory course for all students in Pasture and Range Management Department which must be taken and passed. Students are therefore expected to fully participate in all the course activities and have a minimum of 75% attendance to be able to write the final examination.

READING LIST:

1. Crowder, L.V. and H.R. Chheda. Tropical Grassland Husbandry. Longman, New York, 1982.
2. Skerman, P.J. Tropical Forage Legumes. FAO Plant Production and Protection Series, No. 2. FAO (Food and Agriculture Organization), Rome, 1977.
3. Skerman, P.J. and Reverous, F. Tropical Grasses. FAO Plant Production and Protection Series, No. 23. FAO (Food and Agriculture Organization), Rome, 1990.
4. Robert F.B., Nelson C.J., Kenneth J.M., Colins M. Forages. The Science of Grassland Agriculture, Volume II, 6th Edition. Blackwell Publishing 2003.
5. Whiteman P.C. Tropical Pasture Science. Oxford University Press, New York, 1980.

LECTURE NOTES

Grasses as feed for ruminant animals

The natural feed of the herbivorous animals is forage and for most of the year this forms all or most of the feed of ruminants.

Grasslands/Forage plants may be classified into two main groups as follows.

- (a) Herbaceous plants
- (b) Woody plants

Among the herbaceous plants, two groups are important as sources of forage. These are:

Grasses: They make up the bulk of the plants found in many mixtures of natural vegetation used as forage. They also supply the bulk of the energy content of forages.

Legumes: because these have relatively high nitrogen content in the vegetative matter and their ability to fix atmospheric nitrogen.

Grasses and legumes are found in the various vegetations that constitutes the grazing resource or sources of feed for ruminant animals.

These vegetations are commonly referred to as grasslands which may be divided into two main groups:

Natural grasslands which are not cultivated and managed in any form of deliberate human intervention. This is generally referred to as **natural pasture**.

Cultivated grassland which are cultivated and managed generally referred to as **cultivated, planted or sown pasture**.

Cultivated grassland may also be sub-divided into permanent and temporary pastures. The latter form part of a rotation of crop whereas permanent pastures is intended to remain as grassland indefinitely.

Natural pastures normally include a large number of species of grass, legumes, herbs, shrubs etc whereas cultivated grasslands may consist of single species or mixtures of relatively small numbers of species.

Growth pattern of Grasses

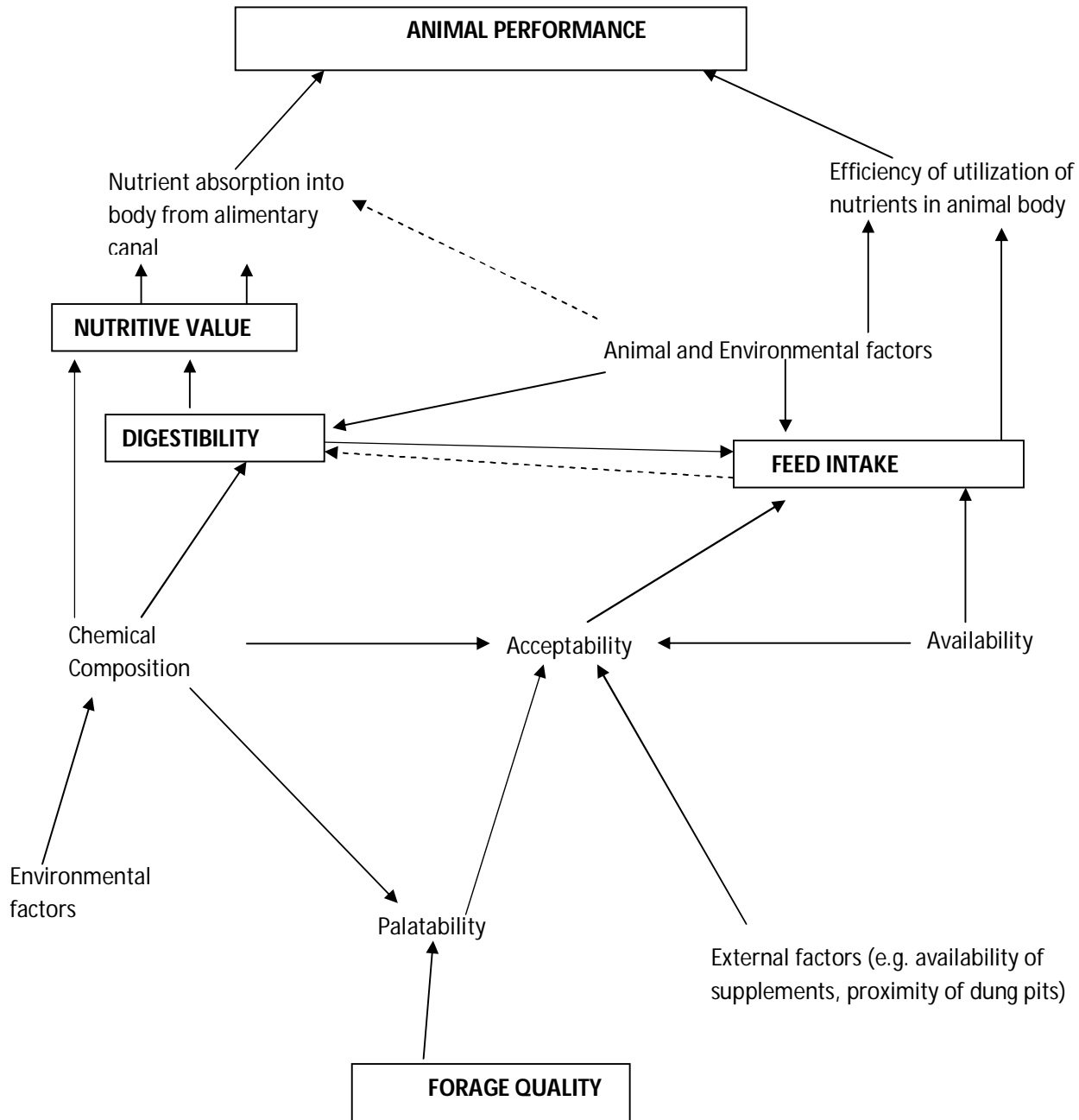
In tropical climates, soil temperature is high enough to permit the growth of grasses throughout the year, but such growth is commonly restricted by insufficient moisture supply for definite periods of the year. The climate is characterized by clearly defined wet and dry seasons but grass growth is very rapid during the wet season and as the soil dries up towards the dry season, the herbage matures and dies, leaving a feed resource that is some time described as 'standing hay'. In cold and temperate climates grasses start to grow in the spring when the soil temperature reach 4 to 6°C. There is a rapid production of leaf followed by an increase in the growth of the stem leading to the ultimate emergence of the flowering head and finally to the formation of seed.

The rate at which grasses grow is dependent upon climate, available nutrients in the soil and the amount of leaf on the plant which intercepts light.

Immediately after harvesting, there is a period of slow re-growth followed by an accelerated rate and finally a period of decreasing growth as the herbage matures. As grass swards increase in leaf area, the photosynthetic capacity of successive newly expanded leaves is progressively reduced because of the increasing shade in which they develop. The rate at which re-growth occurs depends upon the maturity of the crop at the time of harvesting. If the grass is young and leafy it recovers more quickly and starts re-growth earlier than when mature herbage is harvested.

Definition of Forage Quality or Feed Value

Animal performance depends on an inter-relationship between a number of factors both internal and external to the animal itself. The interrelation is shown in the scheme below.



Schematic relationships between different aspects of nutritive value which influence animal performance

As shown in the scheme above, **nutritive value**, **digestibility** and **feed intake** are the main factors which determine animal performance.

These three factors are, in turn, influenced by a number of other factors related to both the animal (e.g. species, physiological status, age, grazing experience, management, etc) and the forage (species, stage of growth/maturity, management, season, location, etc).

Taken together, these three main factors define what is called FORAGE QUALITY. Chemical composition and digestibility are often linked to the term nutritive value, which describes the amount and types of nutrients that the animal can derive from the feed.

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 hemicellulose 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 of 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 facilitates 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

$$Y=16.4205+0.7892x \text{ –Barnes (1973).}$$

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.

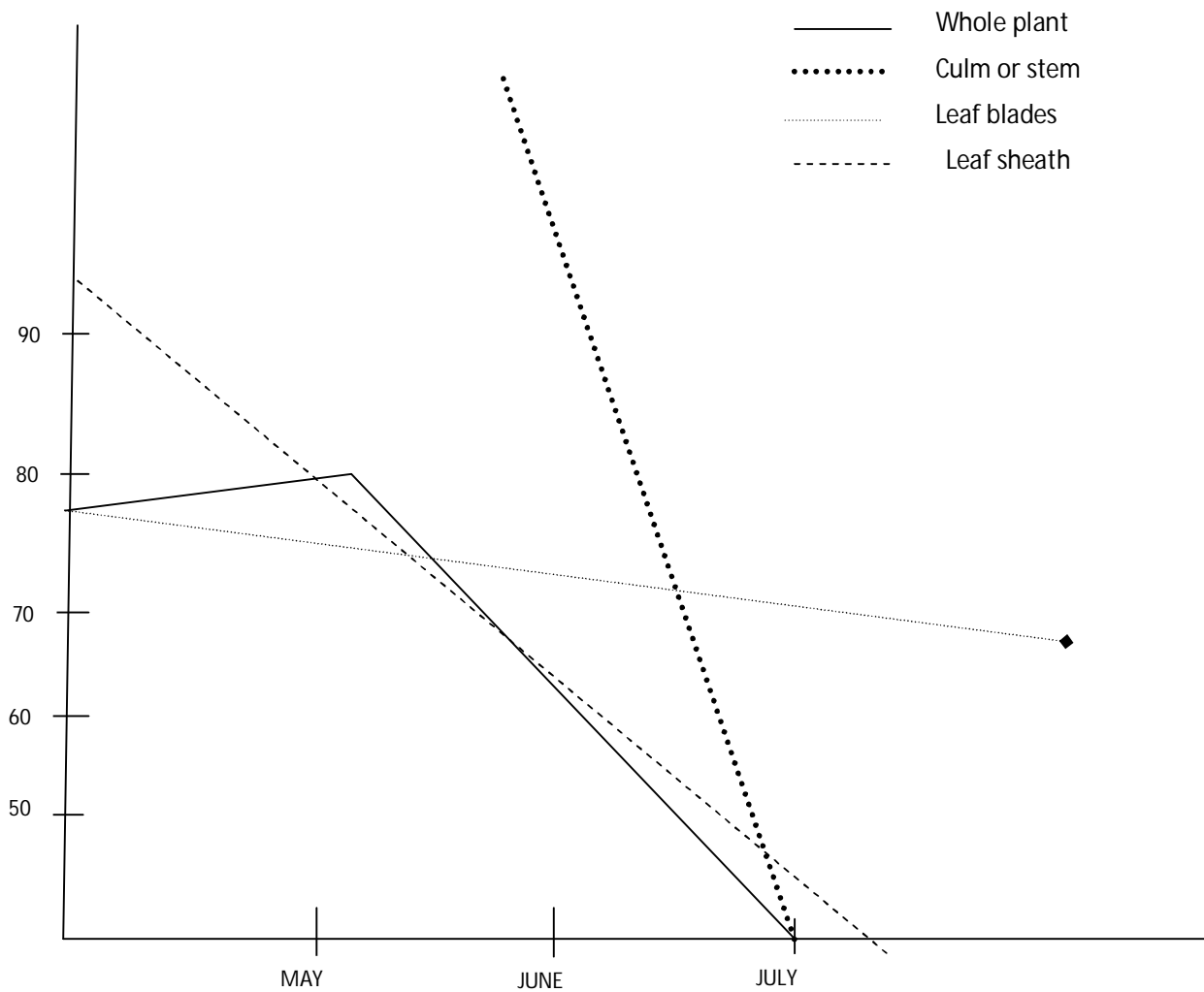
In the Van Soest analysis (Van Soest, 1982), the indigestible residue of the cell wall component, which is made up partially of lignin, is effectively isolated.

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.

PLANT FACTORS AFFECTING FORAGE QUALITY

The mixture of plants growing in a field or ecosystem determines forage quality depending on growing or harvesting conditions. The plant species, growth stage, and conditions at harvest generally dictate quality of the forage. Each of the plant used as forage has a unique morphology and physiology which gives it specific adaptation, growth, and forage quality features. Even though some generalization in terms of factors that affect quality can be made, it is important to recognize the differences in quality that exist among groups of plants, individual species and even cultivars. These differences also interact with stage of growth and the environment.

When reporting animal results from forage-based experiments, researchers should describe the forage species, cultivars, stage of maturity and environmental conditions during growth and characterize the forage with appropriate quality tests.

Some of the plant factors

Species:

The importance of species is seen in temperate and tropical species. The temperate species belong to the C3 category of plants in which the 3-carbon compounds (Phospho-glycerate) is an important intermediate product the in photosynthetic fixation of carbon dioxide. Most tropical species have C4 pathway of photosynthesis in which carbon dioxide is first fixed in a reaction involving the four-carbon compound oxalo-acetate. The low protein content often found in tropical grasses is an inherent characteristic of C4 plant metabolism. In temperate grasses fructans are the main storage of carbohydrates while in tropical grasses these are replaced by starch.

Soil and fertilizer treatment

The type of soil may influence the composition of the pasture especially its mineral content. Plants normally react to mineral deficiency in the soil either by limiting their growth or by reducing the concentration of the particular minerals in their tissues, or more usually by both. The acidity of the soil is an important factor which can influence the uptake of many trace elements by plants. Liberal dressing of fertilizers can markedly affect the minerals content of plants and application N-fertilizers is also known to increase leaf area and rate of photosynthesis. As a consequence, the CP content of subsequently the amide and contents are

increased. Application of N-fertilizer also depresses the water soluble carbohydrates content of temperate grasses which may have an adverse effect on fermentation if the crop is used preserved as silage. Fertilizers may also affect indirectly the nutritive value of a sward by altering the botanical composition. For example, legumes do not thrive on a lime deficient soil, while heavy dressing of N encourages growth of grasses and depresses legumes growth.

Grazing system

In grazing systems that encourage accumulation of mature dry matter due to improper stocking rate, the nutritive value of the herbage on offer is constantly low. However, if the available forage is not limiting, animals have the opportunity to graze selectively and they are able to compensate to some extent for the general fall in nutritive value by selecting plants or plant parts that are higher in nutritive value than the rest. If the grazing pressure is also abnormally high, selection by animals is also reduced and the pasture plants may also be depleted of foliage and their root reserves are also depleted and they fail to regrow. Both under- and over grazing of pastures may change their botanical composition and therefore the nutritive value of their herbage. The quality of forage could be better in the rotational system of grazing in which pastures are grazed for short periods at a high stocking rate and grazing pressure. Under this situation animals harvest most of the herbage on offer and the pasture is then rested for longer periods for recovery.

Other factors affecting the nutritive value of forages

Factors such as climatic as climate and season may influence the nutritive value of pastures. The concentration for example, can be markedly influenced by the amount of sunshine received by the plant. Generally on a dull day the soluble carbohydrate content of grasses will be lower than on a fine sunny day. Rainfall can affect the minerals composition of pasture herbage. Calcium for example tends to accumulate in plants during periods of drought but tends to be present in smaller concentration when the soil moisture is high. On the other hand phosphorus appears to be present in higher concentrations when the rainfall is high. Early season forages are also noted to have lower net energy value than mid-late season forage even when the two are cut at the same stage of growth and are equal in digestibility.

MINERAL IMBALANCE IN FORAGES

Minerals are required for virtually all vital processes in the body. A deficiency of each essential macro or micro mineral in animals results in abnormalities that can only be corrected by supplementation of the deficient mineral.

Where a particular mineral elements are deficient in pastures, however animal production or ill health may result both from direct effects of the elements and body biochemistry and indirectly through depressed appetite and reduced pasture intake.

Element (ppm)	Conc. in DM %	Element	Conc. in DM
Nitrogen	1.8	Fe	30
P	0.22	Mn	40
K	0.31-0.44	Zn	20-40
Ca	0.22-0.35	Cu	4-10
Mg	0.12	Co	0.1
Na	0.05	Iodine	0.12
Fe	30	Se	0.05

Recommended contents of mineral elements in diets of beef cattle weigh 300-500 kg (Minson *et al.* 1975).

Increases in pasture intake have been reported by feeding supplementary nitrogen, P, Na, S, Se and Co (Minson, 1976).

Apart from the presence of the particular mineral elements in the right quantity in the pasture their appropriate balance is also important to ensure optimum animal performance making the study of mineral nutrition in animal complex.

Direct supplementation of animals has been compared with application of the deficient element to the pastures. Rees Minson and Smith (1974) measured voluntary intake and *in vivo* DMD of pangola grass (*D. decumbens*) grown with and without S fertilizer to sheep either with or without S supplementation. S fertilizer increased S content of the pasture from 0.09 to 0.15%, increased DM yield from 2100 to 4200 kg/ha and increased leaf percentage from 13 to 23%. When fed to sheep in pens, S fertilizer gave a larger increase in voluntary

intake than supplementation while both increased DMD similarly. S deficiency apparently depresses microbial activity in the rumen so that increasing S level increased DMD, similarly. However the increased intake due to S fertilization could be related to higher leaf content in the pasture and a shorter retention time in the rumen. In a similar study Rees and Minson (1976) examined the effects of Ca fertilizer on *D. decumbens*. In this case supplementation had no effect on intake or digestibility whereas fertilization increased both. Increased digestibility resulted mainly from increased digestibility of the hemicellulose fraction while increased intake was again related to the shorter retention time in the rumen. Rees and Minson (1976) suggested that Ca fertilizer effects may be related to changes in the cell wall compartments allowing an increased rate of microbial breakdown in the rumen.

There two examples demonstrate the important interactions between mineral nutrients, pasture components and the nutritive value of pastures. Correction of nutrient deficiencies in pastures may not only increase pasture growth and yield, but also improve the nutritive value of the pasture through effects on intake and digestibility.

The nutritive value of pastures discussed mainly in relation to digestibility and intake but these factors are seen to be modified by interaction between specie stage of growth environment and soil nutrient effects. Nutritive value may also be modified by management practices.

ANIMAL DISORDERS CAUSED BY FORAGE CONSUMPTION

BLOAT

Bloat or rumenal tympani occurs when the gaseous products of fermentation within the rumen and the reticulum are unable to be removed by the normal process of eructation (belching). This can be done either to the development of a stable foam with rumenal content (frothy bloat) or to the failure expel the free gas owing to some physical or mechanical interference with oesophageal or rumen functions. Frothy bloat can develop at any time of the year and on any type of pasture, but tends to be more common in the early season when the pastures are very fresh and the leaves are young, or on legume dominated pastures. Frothy bloat is dietary in origin and occurs particularly in cattle grazing pasture with high legume content or high quality legume hay. It is not a major problem on tropical pastures. Methane in one of the grasses responsible for bloating. Incorporation of the growth promoter. Monensin decreases methane production and the incidence of bloat. Chemical methods of treatment and

control through the use of anti-foaming or foam breaking agents have been the major methods of control for many years.

Photosensitization

Photosensitization in ruminants occurs when circulating compounds within the blood come into contact with light in blood vessels in the skin. The agents obtain energy for chemical activation by absorption of light. These photodynamic agents may themselves not cause tissue damage, but the energy they create can be passed on to other compounds which become chemically reactive and produce lesions. The lesions they produce are a reddening (erythema) and oedema (swelling) of the skin with a resultant leakage of fluid and subsequent scab formation.

Primary photosensitivity occurs when the photosynthesizing agent is a specific photodynamic compound contained in the ingested plant material. This pigment is unchanged by liver action, enters the blood stream in the active stage and on exposure to light produces the characteristic lesion on the skin of animals. Some of the species that can cause primary photosensitivity is *Lolium perenne*, ryegrass, *Panicum*.

Secondary photo-sensitivities: Occur when toxic agents within the ingested plant material, produce liver damage which obstructs free flow of bile causing jaundice and preventing the liver from excreting phyllo-erythin, a pigment resulting from ruminal breakdown of chlorophyll.

Mycotoxins

These are poisonous substances of plant origin which after entrance into the body of the host animal produce signs of diseases or can result in production losses as a result of sub-clinical effects e.g. facial eczema (*Sporodesmin* poisoning), Ryegrass staggers (RGS), Paspalum staggers, Mycotoxicoses (feeding of fungal-contaminated conserved feeds).

Phyto-estrogenic effects: A group of chemical compounds occurs in some plants particularly legume which have an action similar to that of naturally occurring hormones within the animal body e.g. phyto-estrogens present in legumes, which mimic the action of mammalian oestrogens and cause marked changes to structure and function of the reproductive organs especially in females.

Mineral deficiencies

Pasture and other food sources contain mineral elements which are required for normal functioning of the ruminant animal. These are commonly classified into two groups depending on the degree of requirement. Namely: Macro-nutrients such as Na, Ca, K, Mg, P, Na, S, Cl, and Micro-nutrients (i.e. trace elements) which include Cu, I, Fe, Mn, Se, Zn Mb.

When the availability of one of these elements is reduced and the level within the animal body falls below a threshold value, a state of deficiency which may lead to the appearance of characteristic signs of disease is said to exist. This is known as clinical disease, whereas with many diseases, production losses can occur with no obvious symptoms being present, and this is referred to as sub-clinical disease. The latter state can be common in mineral deficiency.

Hypomagnesaemia or grass staggers is a disorder which can occur in recently calved cows and less frequently in ewes. It is characterized by in-coordination, hyper-excitability and convulsion, followed by death within 1-12 hrs if untreated.

TOXICITIES

Nitrate-nitrite poisoning

N-N poisoning occurs in ruminants when diets are high in nitrate and low in soluble carbohydrates. Ingested nitrates are normally reduced to nitrites and finally to ammonia but when nitrate levels are high the rate of reduction to nitrite is slowed leading to an accumulation of highly toxic and readily absorbed nitrites. These nitrite ions combine readily with haemoglobin to form meth-haemoglobin which interferes with the ability of blood to transport oxygen. The animal dies from anaemia (absence of oxygen when about 60% of the haemoglobin has been immobilized). Levels of nitrate in the pasture as high as 2% of DM could be dangerous.

Cyanide poisoning- as a result of consumption of cyanogenic plants. Cyanogenic plants include reed sweet grass (*Poa aquatica*); native couch (*Brachyachne convergens*), Johnson grass (*Sorghum helepens*), Sorghum (*Sorghum vulgare*) and Sudan grass (*Sorghum sudanenses*), white clover.

Acidosis

Commonly associated with excess grain ingestion but can also occur on pasture. Acidosis results from excess intake of feeds rich in starch and other carbohydrates which gives rise to an abnormal acid fermentation within the rumen involving excessive production of lactic acid. As the lactic acid level increases, normal rumenal flora are destroyed and the rumen pH falls below 5.0 (normally 6.0 -7.0 in pasture- fed animals). Can occur in pasture as a result of significant increase in the palatability of the feed on offer as a result of feed deprivation for a time before access to carbohydrate rich feed is allowed, can cause dehydration, diarrhoea, abortion, lameness and death.

Tannins

Tannins are separate into two groups, condensed and hydrolyzable tannins. Condensed tannins also referred to as proanthocyanidins are substances with a molecular weight from 500-3000. Hydrolyzable tannins are derived from gallic acid and polyols usually glucose. These tannins may be hydrolyzed by acids or bases to yield a sugar or gallic acid. The most observed effect of simple polyphenols in the diet has been reduced intake. The mechanism of the reduction is not known and may either be nutrient digestion or disruption of metabolism. These mechanisms could include reduced palatability by binding to protein or taste receptors and reduced digestibility by binding to digestive enzymes (protein) or to substrate protein. One of the most beneficial effects of tannins is prevention of bloat and protection of protein against rapid rumenal degradation. According to Price and Butter (1980) the adverse effects of tannins may be observed as

1. Depressed feed intake
2. Binding dietary protein
3. Complexing with digestive enzymes
4. Binding with endogenous protein
5. Interacting with the digestive tract and
6. Direct toxic effects

Even though Fahey and Jung (1989) concluded that there is no evidence that tannins themselves are harmful condensed tannins may have beneficial and detrimental nutritional effects. The beneficial effect comes from binding with protein and thus increasing the amino acid available for post-ruminal absorption. Tannins in excess of those bound to protein are free and are probably responsible for decreased intake and ruminal carbohydrate digestion.

Alkaloids

These are compounds formed from some important amino acids such as tryptophan and are common in some species of grasses (e.g. *Phalaris aquatica*) and legumes such as lupine and tall fescue.

Their effects on animals include acute cardiac disorder and sudden death, chronic nervous disorder and sudden death, chronic nervous disorder characterized by tremors, staggers or diarrhoea and low voluntary intake, respiratory depression and failure, general hypotension and inhibition of muscular transmission, death may occur in animals that consume over a short period large quantities of mature plants containing seedpods and seeds. Chronic toxicity may be observed by reduced growth rate due to methionine deficiency.

Pasture quality

The attainment of production goals depend on the feeding values of the pasture which reflects the level and balance of nutrients which it contains.

The potential digestibility of pasture material conveniently falls into four plant fractions.

1. The readily hydrolysable carbohydrates such as the monosaccharides, disaccharides, fructosans and starch, proteins, minerals, and some cutins, which are potentially fully digestible.
2. Higher molecular carbohydrates including cellulose and hemicellulose, which are not protected from digestion and which are potentially digestible.
3. Higher molecular carbohydrates which are fully protected by lignin or cuticle and which are not digestible.
4. Indigestible lignin, silica, and cuticle.

These groups are complex and are variable in character and are each composed of many different compounds so that their behaviour is not fully predictable. The cellular contents belong to the first group, while the cell wall constituents and epidermis are spread over the other three groups.

Relative proportions of the four fractions vary in different plant organs depending on the state of development and maturity and the proportions of anatomical tissues present. Leaf is higher in digestibility than stem (young stem could be of equal digestibility as leaves), lamina is more than leaf sheath. Midrib of lamina is poorly digested. Senescent materials low in OMD and intake.

FORAGE CONSERVATION

Ruminant animals are primarily forage consumers. A major challenge to livestock producers is assuming adequate quantity of quality feeds throughout the year. Forages grow rapidly during the wet season, become fibrous, coarse and low in nutrients as the season advanced towards the dry season. This is because tropical grasses grow and mature under a high temperature regime. High temperature stimulates growth and ageing of grasses with a consequent fall in intake and digestibility by ruminant animals, which eventually hamper development of the animal.

In order to solve the limitations of feeds for ruminants especially during dry season, there is a need for developing the feed conservation strategy during the period of abundant supply (rainy season) so as to redistribute the feed supply over the year to meet the requirements of livestock resources.

Forage conservation basically aims to produce, at low cost, a stable product suitable for ruminant animal feeding with minimum loss of nutritive value. It also bridge the gap between the feed requirement of the animals and the production of the forages.

Why conservation

1. To prevent wastage of excess yield of rainy season.
2. To preserve quality of forage material year round.
3. Increase the nutritive value and palatability of forage materials.
4. Reduce the cost of feeding of the animals, thus reduce cost of production.
5. To reduce the competition of livestock with man for staple food.

DIFFERENT METHODS OF FORAGE CONSERVATION

A. HAY MAKING

Hay can be defined as animal feed produced through dehydration of green forage to moisture content of between 15-20% which is low enough to inhibit activities of plant microbes and enzymes and without deterioration of nutrients. *Pennisetum clandestinum*, *Panicum maximum*, *Cenchrus ciliaris*, *Cynodon* spp. and *Digitaria decumbens* are examples of forages used to make hay.

To produce hay of high quality, it is essential to harvest at the right time. When fodder is harvested too early, its moisture content is too high resulting in hay with reduced dry matter content. If harvesting is delayed, the plants develop high lignin content, which is of poor quality because of its low digestibility. Crop should be cut at the early bloom stage.

Steps in Hay making

1. Select a suitable plant material(s).
2. Cut the materials when grasses have just brought out their flowers in order to obtain the most nutritious and palatable product. Cutting can be done manually (knife) or with a mower.
3. Use machine roller to crush plant stem to facilitate drying (Crushing stems at time of cutting will cause stems to dry at more nearly the same rate as leaves).
4. Drying or cure the material to the desired moisture content. Rapid drying of the crop conserves the carotene more efficiently.

Drying could take any of the following forms

- i. Allow the fodder to dry 'by self' along row in the field.
- ii. Spread over an upright stake with several horizontal cross bars on the field.
- iii. It could be spread on the roof of houses.
- iv. It could be spread on wire or drying tray strung between poles and blow hot air from beneath of between 135-190⁰ C with the aid of heater.
- v. Spread on the floor of heater room (stove, cooker, bulb)

Note that the main aim of this is to allow the fodder to dry without spoiling in a wet climate and prevent attack of termites, thus the drying method adopted will depend on the prevailing weather.

5. Racking, packing and baling with Hay baler. Note that Hay baler could be manual or automatic baler. (BALING is a method of packing so as to achieve reduction in the amount of storage space required. Compressing the loose hay into a package which can be handled and stored conveniently).

6 Store the hay in termite free environment as hose hay, baled hay, chopped hay, milled hay, pelleted hay/flacking(to make it palatable for animals)

Methods of Determining Moisture Concentration

Forage moisture concentration can be quickly estimated using one of three methods: the hand method, measurement with a moisture tester and drying forage in a microwave.

Hand Method

The hand method, also known as the grab test or squeeze test, is a crude method to estimate forage moisture concentration. It also takes a lot of experience to perfect the technique needed to use this method. To approximate the moisture concentration of hay, take a handful of forage, twist it tightly, and release. Hay should not be baled if the forage is brittle and falls apart (too dry) or stays wadded up or slowly untwists (too wet). Hay that springs open and fluffs out upon release is at right moisture concentration and is ready to be baled. If hay is too dry, wait until the humidity increases in the evening before baling.

B. SILAGE MAKING

Silage is the moist succulent feed produced by fermentation of green forage which are compressed and stored for a period of time under an anaerobic condition. Harvest silage at 30 to 35%DM or 65% moisture. The first essential objective in preserving crops by natural fermentation is the achievement of anaerobic conditions. The nutritional value of the silage produced depends on the species, stage of growth and handling during ensiling.

Ensilage is the name given to the process of silage making while Silo is the container in which silage was made. Silage making is less dependent on the weather condition unlike Hay making.

Panicum maximum, *Pennisetum purpureum* and *Setaria anceps* are e.g. of forages that are suitable for silage-making. Crops such as maize, sorghum and millet with or without legumes are also used.

Lactic acid bacteria brings about rapid fermentation in the ensiled materials and produces natural organic acids which prevent further changes in plant composition.

In summary, the processes/steps in silage making are

1. Prepare the silo, wash, clean and disinfect, if possible fumigate (in fumigate, you'll wait for two weeks before use).
2. Cut the forage of green crops.
3. Wilt partially (to 30-35 dry matter, not dry) to increase the percentage dry matter.

Note that the lower the moisture content of the silage material, the lower the bacterial activity in silo and the better the silage, so wilt partially to reduce the H₂O content).

4. Chop the materials to small bits of 2-4 cm
5. Crush the stemy part to aid consolidation.
6. Pack or stack the forage to the silo

Note that this should be done rapidly within a day to reduce aerobic bacterial.

7. Ensure proper consolidation

Consolidation could be done either manually or mechanically in large scale like Tractor/Bulldozer.

Silage is meant to create an anaerobic conditions for the fermentation process.

8. Add all necessary additives, urea, molasses or poultry manure.

Additives – to improve fermentation, increase nutrient status and to improve flavour. It also serve as preservatives and sweeteners.

9. Seal off the silo this is to prevents re-entry and circulation of air during storage so as to initiate fermentation process. Silo should also be free from penetration by rain. Weight such as tyres, plants, stone should be put on top of the silage.

10. Leave for at least 3 weeks to mature.

The squeeze/ grab test

After wilting the forages, there is need to determine the right moisture content (MC) or dry matter (DM) % before using it to make silage. A simple test can be carried out to determine the right condition. Squeeze a handful of chopped material as tightly as possible for 90

seconds. Then release your grip. If a squeezed fistful forces free juice into your hand and the ball holds its shape when pressure is first released, then the forage is too wet. When the forage reaches 60 to 65% MC, the ball will momentarily hold its shape after squeezing, then gradually expand. There should be no free juice on your hand. This is the right MC. When the forage gets too dry, the ball will spring open and quickly fall apart when released.

Four Stages involved in Silage making

1. Aerobic stage – plant respiration continues after the Silo is filled and until the oxygen present in the air and trapped in the forage is used up. pH is also high (6.0-6.5). High air results in rise in temperature.
2. Fermentation stage – lactic acid bacteria ferment the naturally occurring sugars (mainly glucose and fructose) in the crop to a mixture of acids, but predominantly lactic. The lactic acid produced increases the hydrogen ion concentration to a level at which the undesirable bacteria are inhibited.
3. Storage stage – when the Silage is sealed and no air penetration.
4. Unloading stage – for feeding ruminant animals.

C. HAYLAGE

Haylage is a grass crop which is cut, harvested, and stored for feeding farm animals. It is made from the same crops as normal hay, but with a higher moisture content.

Common crops are alfalfa, clover, and Bermuda grasses, but other grasses and legumes are suitable for this storage technique.

In UK up to 60% of all horses and ponies suffer from undetected respiratory disease. The most common cause of respiratory disease is an allergic reaction to the dust and millions of mould spores found in hay, so it is very important to take steps to reduce the levels of dust and spores. It is cut just like hay but, instead of being allowed to dry out completely, it is baled when the dry matter reaches 65 to 75%. Then wrap with plastic to exclude all air from the bale and allow a very mild fermentation to take place to preserve the bale with no wastage. Leave for 8 to 10 weeks.

OTHER FEED RESOURCES IN THE DRY SEASON

Crop Residues

Is the residues of annual crops of corn, wheat and soybeans after harvesting.

The annual crops of corn, wheat and soybeans produce million tons of residues after harvest, most of the material is left in the field after green harvest.

As the demand for direct use of cereal grains increases, the role of crop residue and by-product feedstock will become increasingly important.

Crop residues are low in N and high in crude fibre, these restrict intake and digestibility as a result underfeeding results. Improved handling by chemical and physical treatments can improve their quality and this is necessary to enhance the utilization of fibrous feedstuffs by ruminants. The purpose of processing is to increase acceptability of high fibre feeds to the animal, thus increasing daily feed intake and to enhance rate and (or) extent of digestion, thus increasing nutrient availability.

Physical treatments may include grinding, chopping or steam treatment while chemical treatment involves the use of chemicals such as nitrogenous compounds (ammonia and urea), and alkalis (sodium hydroxide). Soak for 1-2 days in a dilute solution of NaOH, then wash exhaustively to remove excess alkali. This breaks the fibre linkage and causes carbohydrates to become more available to the microorganisms in the rumen.

STORING AND FEEDING CONSERVED FEEDS

Hay should be protected from rain and sun as exposure to these factors reduces its feed value. Leaching by rain causes a loss of soluble minerals, sugars and nitrogenous constituents, resulting in a concentration of cell wall components which is reflected in a higher fibre content. Storage under cover with some movement of air will allow completion of the drying process and reduce the absorption of moisture, this will prevent or reduce formation of mycotoxins. Handle the forages with care during hay making and storing so as to reduce leaf loss.

It is important to minimise the exposure of silage to air during storing and unloading which reactivates aerobic microbes and moulds which spoil the silage. An average daily removal rate of 6 inches from the face should prevent heating and spoiling of exposed silage. Silo must remain airtight and must be free from penetration by rain.

Feed haylage in a raised hay platform or wagon with sides to minimize loss. Haylage which lays on the ground and is stomped on by animals will usually not be eaten and be contaminated.

Supplementing with forage legume is a sustainable way of improving the feed value of poor quality crop residues, e.g. *Stylosanthes guianensis*, *Leucaea leucocephala* etc. Fodder from trees is especially useful during the dry season when it is used to supplement roughage or hay.

Measure animal requirement and don't allow animal to go to where the feed is kept to feed themselves.

FEEDING VALUES OF CONSERVED FORAGES

Properties of good silage

A. Physical properties

- i. Acceptable aroma(ammonia odour)
- ii. A pleasing taste/high palatability.
- iii. A greenish yellow colour.
- iv. Should not be mouldy, shiny or rottened.

B. Chemical properties

- i. Must possess at least 35% dry matter content.
- ii. The pH should be 4.0-4.5.
- iii. Temperature – between 29.4-35⁰C in the silo.
- iv. Lactic acid -1.5-2.5%
Acetic acid -0.5-0.8%
Butyric acid -0.1 %
- v. Ammonia Nitrogen should be 5-8% of total Nitrogen.
- vi. 3% sugar content in herbage for ensiling.
- vii. 55-70% digestibility

Indicator of Hay Quality

Hay that is early cut, green, leafy, soft, free of foreign material, and has a pleasant odour (clean crop odour) will be of high quality.

HEALTH HAZARDS ASSOCIATED WITH CONSERVED FORAGES

In the production of hay of variable moisture on contents, mycotoxins (are toxic substances produced by fungi) may be present which are harmful and have a great effect on ruminant animal and man. Mouldy hay is unpalatable and may be harmful to farm animals and man because of the presence of mycotoxins. Rain may encourage the growth of moulds.

The DM or MC of forage affects fermentation and thus, the acceptability of silage. Silage ensiled too wet will encourage clostridia fermentation (undesirable spp), they produce butyric acid and degrade amino acid to materials of poor nutritive value. This result into a type of silage which ruminant will refuse to eat and consequently a silage of low nutritional value.

Silage put to dry heat during the fermentation process, the protein may become bound and is not available to animal. The productive performance of animals consuming this type of silage is poor as a result of depressed voluntary food intakes and poor utilization of silage nitrogen resulting in high losses. The potentially toxic nature of the amines in badly-fermented silages, together with the possible contamination of milk and cheese with clostridia spores, make it imperative that the production of badly-fermented silage is avoided. Free drainage occurs in most silos and the liquid or effluent carries with it soluble nutrients which results in a marked loss of nutritional value. Crops ensiled with a dry matter content of 150 g/kg may result in effluent DM losses as high as 10%. This result in pollutants ten times the strength of raw sewage.

Where oxygen is in contact with herbage for any period of time, aerobic microbial activity occurs and the material decays to a useless, inedible and frequently toxic product. It is essential to discourage the activities of undesirable microorganisms such as clostridia and entero-bacteria which produce objectionable fermentation produces.