FACTORS LIMITING THE NUTRITIONAL VALUE OF GRAZED TROPICAL PASTURES FOR BEEF AND MILK PRODUCTION

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ABSTRACT

The feeding value of tropical pastures is discussed in relation to the poor performance of grazing animals, particularly dairy cows. Animal production from cattle grazing tropical pasture swards and factors limiting production are considered in relation to variation within and between species, effects of maturity and seasonal differences in nutritional value of herbage. The influence of toxic compounds on production of saleable products is reviewed. The principles of defoliation are discussed in relation to canopy structure, variation in nutrient composition within swards and the large potential for selection when animals graze tropical pasture swards. Grazing behaviour studies show that cattle grazing tropical pasture swards have difficulty consuming large quantities of fibrous feed and when grazing some swards have difficulty satisfying intake requirements due to low availability or inaccessibility of leaf. New approaches are suggested for selecting pastures of high nutritive value and for developing management systems which allow a large proportion of nutrients to be utilised for production.

INTRODUCTION

The true feeding value of a pasture can only be measured in terms of animal production, preferably under grazing conditions (Hutton and Minson 1974). Intake of digestible nutrients largely determines animal performance and the many pasture and animal factors influencing intake of nutrients and thus animal production from grazing cattle are reviewed in this paper. Emphasis is given to factors controlling intake of energy, particularly differences between tropical pasture species, selective grazing and the influence of sward canopy structure upon the cows' ability to harvest feed. Although many of the nutritional principles discussed in this paper have been developed in experiments with dairy cows there is no reason to suspect that these will not apply to beef cattle although their relative importance will vary according to environmental conditions.

EFFECT OF FEED QUALITY UPON ANIMAL PRODUCTIVITY

Production is only achieved when feed is eaten in excess of that required for maintenance and relatively small increases in feed quality will lead to large increases in production. Similarly as calving percentages drop more unproductive stock are being carried and conversion efficiency of the herd is lowered (Stobbs 1974a).

The lactating cow has a very much higher nutrient requirement than the beef animal and is therefore the first class of stock to show up any deterioration in pasture quality. Nutrients required for 1 kg liveweight gain per day equate with only about 8-9 kg of milk per day. This basic principle is seen in the poor productivity of dairy cows when fed a sole diet of tropical pasture and the relatively satisfactory performance of beef cattle on these pastures. Beef cattle grazing improved tropical pastures are capable of producing good gains (0.9-1.2 kg steer^{-1} day^{-1}) over relatively short periods during the early growing season (Smith 1970) but some of this gain may be attributed to compensatory growth. However the decline in herbage quality associated with pasture maturity results in much lower liveweight gains and a review of animal performance from grazing experiments in the tropics (Stobbs 1974a) showed that mean annual gains were 0.35 kg steer^{-1} day^{-1}. Obviously the genetic potential of

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stock can limit performance but even the more productive animals, which are capable of 1.2-1.4 kg day^{-1} L.W.G. when fed grain, rarely have annual liveweight gains which exceed 0.60 kg day^{-1} when grazing tropical pastures (Stobbs 1974a). This would indicate a need to increase the nutritional value of tropical pastures both for beef and milk production.

Since the nutrient requirements for different breeds and classes of stock vary, extrapolation from one class of stock to another, which is often necessary, is not generally to be recommended (Bird 1974). Lactating dairy cows have a number of advantages for evaluating the nutritional value of pastures: 1. *Bos taurus* cows have a higher genetic potential, 2. they respond rapidly to changes in nutritive value of feed and short-term changes can be measured (Stobbs and Sandland 1972), 3. ranking for feeding value is similar to liveweight gain (Stobbs 1973c), 4. in some milking experiments individual animals can be used as replicates which improves precision. Dairy cows early in lactation draw on body reserves for energy but some measure of the intake of digestible energy derived from feed can be made using the fatty acid composition of milkfat (Stobbs and Brett 1974).

Since, in general terms, intake of herbage increases with increasing digestibility, it should be possible to predict from indoor studies the beneficial effect of small increases in digestibility upon animal production. Using data from two experiments (Minson 1971a and 1972) an average increase in digestibility of 4% should lead to an 8% increase in voluntary intake and 20% increase in digestible energy consumption. Since 50% or more of the digested nutrients are required for maintenance this 4% increase in digestibility should lead to about 40% increase in animal productivity. However intake is not perfectly correlated with digestibility and can be affected by physical factors such as the proportion of leaf (Laredo and Minson 1973) and it is essential that field testing of any superior species or management treatments is confirmed in grazing studies. Both protein content and digestibility are negatively correlated with seedling vigour and yield (Clements 1970) making field testing even more essential.

STRENGTHS AND WEAKNESSES OF EVALUATION TECHNIQUES

Both indoor and grazing evaluation techniques have advantages and limitations for investigating the nutritional value of tropical pastures.

Indoor studies

Factors influencing the nutritional value of herbage can be precisely measured indoors where it is possible to determine both the quantity of feed consumed and the quality of the feed. However even if indoor studies are made with animals of the same species, age and physiological status as those which will finally graze the pastures there are many additional factors which can influence animal productivity under grazing. Diets selected by grazing animals can vary greatly from those ingested by animals fed cut herbage indoors. Extra muscular activity involved in harvesting feed can increase the maintenance energy requirements of animals on pasture by 25-50% (Osuji 1974). The nutritive value and water content of herbage is changing continually both within and between days and the efficiency of the grazing animal to handle this situation may be lower than when fed indoors on a ration of constant composition. Harvesting and processing (mainly drying) may alter the rate of feed intake (Osuji 1974) and may change the content of toxic substances. In the tropics and sub-tropics climatic stress (temperature, humidity and rainfall) can influence feeding behaviour (Payne, Laing and Raivoka 1951). Most indoor studies are conducted with individually penned animals but under grazing, social influences, such as the presence of dominant animals, affect the performance of animals within the group (Albright 1974). Factors such as fouling and treading of pastures can deter animals from eating. Other external influences such as flies, mosquitoes, ticks, internal para-

sites and disturbances by animals are variable and effect grazing behaviour and animal productivity to a greater extent in the field.

Although indoor studies are useful for identifying factors influencing nutritive value of pastures, grazing trials must be the final measure of quality since they are the only ones of practical significance.

Grazing evaluation

Animal performance in most grazing experiments is influenced by both the nutritive value of herbage and also the quantity of feed offered. It is rarely possible to separate the contribution of each of these components in experiments aimed at measuring production per hectare. Even when excess feed is available under conditions of lenient stocking there is usually an accumulation of herbage throughout the main growing season (Stobbs 1969) which influences the nature and stage of maturity of swards being grazed.

The rate of liveweight gain or level of milk production from a pasture will depend on the nutritive value of the feed provided that the quantity of pasture available is in excess of the animal requirements and genetic potential has not been reached (Ivins, Wilnot and Davison 1958). By leniently stocking pastures at a particular stage of regrowth it is possible to measure maximum animal performance from that pasture and thus the potential nutritive value of the pasture. Temperate pastures are comparatively homogeneous and Greenhalgh and Reid (1968) have shown that there is no increase in animal productivity from allocating more than 20 kg DM per cow per day. With tropical pastures there is some difficulty in estimating the amount of pasture which constitutes excess because greater selectivity of the more nutritious parts of tropical pastures is possible with a consequent increase in animal productivity when larger quantities of feed are offered. Jones and Sandland (1974) have shown linear increases in annual liveweight gain per animal with decreasing stocking rate over a large range of stocking rates. The effects of grazing pressure are of greater interest but only limited data are available for comparison. A curvilinear relationship will occur (Mott 1960) but the level at which production peaks is likely to vary between seasons and between pastures.

Although maximum production from swards can be measured using low grazing pressure techniques, as the pasture is grazed down the diet selected by grazing animals is influenced by the degree to which pastures are defoliated. Because of this dynamic situation objective short-term grazing experiments to compare the nutritional value of pastures in terms of animal production are virtually impossible to design.

Measurement of herbage intake

The nutritive value of pasture is continually changing and it is often desirable to measure short-term changes in feeding value. Although there are dangers involved in relying upon characters correlated with animal production there is some justification to select pastures which are consumed in large quantities (Milford and Minson 1966a). Despite intensive research during the past 30 years techniques for the precise estimation of the intake of grazing animals have not yet been developed, other than for predicting large differences ($> 25\%$) between herbage treatments (Langlands 1974). The complexity of factors influencing intake would suggest that one simple laboratory predictor of intake is most unlikely.

VARIATION IN NUTRITIONAL VALUE OF GRASSES AND LEGUMES

Energy and protein deficiencies

Indoor studies with cattle fed tropical pastures have shown that the level of animal production is proportional to the daily intake of digestible dry matter (Holmes, Franklin and Lambourne 1966). Therefore production depends on both the quantity of food eaten each day and the digestibility of the feed. Minson and McLeod (1970)

have shown that tropical grasses are an average of 13% less digestible than temperate grasses and the high level of indigestible fibre leads to a lower daily intake of feed and consequently lower animal production (Stobbs 1974a).

Feed intake is further depressed if herbage is deficient in protein and minerals (Milford and Minson 1966a). Young pastures usually contain sufficient protein and minerals to meet requirements of the animal and production is limited by the intake of digestible nutrients which is in turn controlled by the fibre content of the feed. As pastures mature the fibre content increases leading to a reduction in digestibility and voluntary intake. There is also a fall in the protein and mineral content of the herbage and under some conditions the voluntary intake of these feeds is no longer limited by their fibre content but is limited by a shortage of either protein or one of the mineral elements. Overcoming these deficiencies by feeding supplements, such as urea (Winks, Alexander and Lynch 1970) and phosphorus (Bisschop 1964) removes this limitation on intake. The critical crude protein required in a pasture before intake is reduced by nitrogen deficiency has been estimated at between 6.0 and 8.5% (Milford and Minson 1966b) and recommendations for the dietary content of mineral elements for various classes of stock have been given by the A.R.C. (Anon 1965). With an increased incentive to develop plants with low mineral requirements, such as *Stylosanthes* spp., there is a need to intensify research work on supplementation to exploit the full potential of these pastures by eliminating mineral deficiencies.

Grasses

Large differences in digestibility and intake are to be found between and within tropical grass species when fed to sheep in pens (Minson 1971b). Smaller but still substantial differences in the ability of tropical pastures to supply nutrients for milk production have been measured (Stobbs and Thompson 1975). *Digitaria decumbens* has consistently proved superior to other tropical grass pastures because of a higher intake of digestible energy when cows graze this pasture (Stobbs and Sandland 1972). Reasons for this higher intake are not clearly understood but could be related to the high soluble carbohydrate content in pangola herbage (Minson 1967). Only one critical beef experiment aimed at measuring the potential nutritional value of six tropical grass species, using the lenient grazing pressure technique, has been conducted (Evans and Hacker 1973). Over the first year of the experiment steers averaged 0.48 kg steer^{-1} day^{-1} with highest production from *Setaria anceps* cv. Narok and *Setaria splendida* compared with animal performance from *Digitaria decumbens*, *Setaria anceps* cv. Kazungula and *Pennisetum clandestinum*. In subsequent years differences in animal production from steers grazing these species were small indicating that there is little variation in feeding quality between these grasses. Levels of production were however lower than from cattle grazing some of these species in other experiments (Evans and Bryan 1970).

Legumes

The voluntary intake of tropical legumes is usually higher than that of tropical grasses when fed to sheep indoors (Milford and Minson 1966b) due to a shorter retention time in the rumen and a greater packing density (Thornton and Minson 1973). Adding legume to pasture would be expected to increase liveweight gain and milk production and in fact Evans (1970) and Norman (1970) showed that beef production was proportional to the proportion of legume in the sward. Similarly *Lablab purpureus* was able to maintain a relatively high production in contrast to tropical grasses (Hamilton *et al.* 1970) and good milk production has been obtained from cows grazing *Leucaena leucocephala* (Stobbs 1972). *Trifolium semipilosum* based pastures have proved to be quite outstanding with milk yields from Jersey cows averaging 16 kg cow^{-1} day^{-1} over extended periods (Stobbs 1973c) and have also consistently produced high liveweight gains (Jones and Jones 1973) indicating the high nutritive value of this species. However, lower milk production has been obtained

from cows grazing pure stands of Siratro (*Macroptilium atropurpureum*) and Greenleaf desmodium (*Desmodium intortum*) compared with nitrogen fertilised pangola (Stobbs 1971), possibly due to the difficulty cows have in harvesting the leafy fraction of the legumes (Stobbs 1973a). Cows grazing Greenleaf desmodium produced more milk than cows grazing Siratro despite a lower *in vitro* digestibility which may have been caused by tannin (McLeod 1975). Pure stands of such trailing legumes are obviously not typical of farm practice and better production has been obtained from grass/legume mixtures, the legume being particularly beneficial in the early dry season.

Seasonal effects

The need to measure animal performance in each season throughout the year to fully understand nutritive value of pastures has recently been demonstrated by comparing seasonal variation in milk production from cows grazing three-week old regrowths of four setaria cultivars (Nandi, Kazungula, Narok and Splendida) with pangola and kikuyu grass (*Pennisetum clandestinum*). The ranking order varied markedly between seasons (Stobbs 1973c). Highest animal production which occurs early in the growing season can partly be explained by the higher digestibility of early formed tillers (Wilson 1973). Blydenstein *et al.* (1969) were able to relate depressions in milk production to periods of growth when pangola produced inflorescence. Planting non-flowering varieties, provided that they persist, or planting species with differing flowering habits could possibly allow increased production from high producing stock. There are marked seasonal effects upon leaf/stem ratios, nitrogen and dry matter content of pangola (Salette 1973) which could explain seasonal variation in production since leaf is eaten in much larger quantities than stem of a similar digestibility (Laredo and Minson 1973).

Despite the growth of young nutritious herbage at the commencement of the rains this is usually a period of weight loss or poor growth (Walker 1969). Reasons for this poor performance have not been clearly defined and further research on the influence of rainfall on green pick and animal performance is required.

Maturity

The effect of pasture maturity upon animal production is recognised by every farmer and as far as practicable he attempts to feed young material. A large proportion of the total herbage production is however grown over a relatively short period and hence it is usually not practical for a grazier to control the maturity of feed offered to stock. This would indicate a need for species with a longer growing season and a slower rate of maturity even if total herbage yield is sacrificed, and more intensive studies of grazing management to obtain better animal performance from standing hay. The only tropical grass which maintains a high digestibility with advancing maturity is sugar cane but animal production from animals grazing standing crops has not been good.

Toxic factors

Some toxins and undesirable compounds influence potential productivity and also quality of the saleable meat and milk. Tropical pastures are relatively free of such anti-quality components (Hutton 1971), those which affect milk products have been reviewed by Stobbs and Thompson (1975) and those affecting beef by Stobbs (1974a).

INFLUENCE OF SELECTION ON THE NUTRITIONAL VALUE OF THE DIET

Although cattle are less selective than sheep they still show remarkable skill in selecting leaf from tropical pasture swards. When cattle graze mono-specific swards the uppermost leaves are eaten first, followed by leaf-bearing stem and finally if cattle are forced to it by strict rationing, the almost leafless stem. One rarely finds cattle

grazing down a small area to leafless stem whilst more leafy herbage is still available, except when herbage is fouled by excreta. At low grazing pressure cattle can therefore compensate to some extent for low quality feed by selectively grazing the more nutritious parts of the sward (Stobbs 1973b) but the upper level of production is obviously limited by the nutritional value of the highest quality diet which can be selected from a sward (Hamilton *et al.* 1970). Conversely removal of leaf from the sward reduces the potential for selection and as swards are defoliated grazing animals are forced to consume diets with a lower leaf content.

Unlike temperate pasture swards which have a fairly constant nutrient content from the top to the bottom of the sward, tropical pastures vary greatly in composition (Stobbs 1973a, 1973b). The nutritional value of the diet selected from a pasture therefore depends upon the degree of defoliation and as a pasture is grazed down animals are forced to eat herbage which contains more stem and is lower in digestibility, nitrogen and some minerals. When high yielding tropical pastures are grown on mineral deficient soils a serious dilution of nutrients can occur (Stobbs 1975) which greatly reduces the potential for selection. Some indication of the potential for selection can be obtained by comparing the nutrient content (dry matter digestibility, nitrogen etc.) of cut swards with the content of hand plucked or fistulae samples (Stobbs 1974b).

The dry matter content of leaf and stem varies markedly within the sward, the highest dry matter content being in the base of the sward. Water consumption has been suggested as limiting feed intake but recent evidence suggests that this is not likely unless dry matter falls below 13-15% (Wilson 1974). This rarely occurs with tropical grasses and would therefore only be important when animals are selecting leaf from the uppermost layers of the sward.

The problem of selection is even more complex with mixed swards because of animal preferences. The material selected by grazing animals is dependent upon many factors, the most important being the species and species combinations grazed, season of grazing, stage of growth, sward structure as well as individual animal preferences (Arnold 1964). In spring and summer tropical grasses are greatly preferred to tropical legumes although *Leucaena leucocephala* is preferred to most tropical grasses. *Macroptilium atropurpureum* is not eaten in large amounts during the spring and summer months but can become an important constituent of the diet in autumn; recently conducted indoor feeding trials suggest that this is due to changes in the legume rather than a lower palatability of the associated grass in autumn months (Stobbs unpublished).

Sampling with fistulated animals (Minson *et al.* 1976) provides a measure of the chemical and botanical composition of the diet selected but in order to understand the site of selection it is suggested that studies of canopy structure, plant structure and the distribution of nutrients within swards is highly desirable.

CANOPY STRUCTURE AND EASE OF HARVESTING

An adult animal selectively harvests 30-70 kg of fresh herbage daily, which over a 10-year lifespan could exceed 200 tonnes of feed. In addition this material is carefully chewed at the time of harvest and later in the act of rumination. It is therefore reasonable to expect that grazing behaviour reflects variations in feed intake and the quality of herbage eaten.

Canopy structure and intake

Cows draw herbage into their mouths with each sweep of the tongue and tear it from the sward; the distribution of herbage in the canopy, particularly leaf, can influence the ease with which they can select (Stobbs 1973a). To simply measure herbage yield without describing its physical distribution may therefore give no idea of the ease with which the feed can be harvested by the animal (Stobbs 1973b). The desirability of measuring dried green material rather than total dry matter yield has

been emphasised by Yates *et al.* (1964) and Mannetje (1973) but this measurement has some limitations. For example the leaf content of immature swards may be fairly low but easily accessible whereas the leaf content of mature pasture swards may be high but much of this will be in the lower strata and inaccessible because of stem.

Recent studies on the vertical distribution of herbage within tropical pasture swards (Stobbs 1973a, 1973b) show that despite the high dry matter yields from tropical pasture swards they are loosely packed compared with temperate pasture swards; sward bulk densities (kg ha^{-1} cm^{-1}) vary between 14 and 200 compared with a range of 160-410 kg ha^{-1} cm^{-1} recorded from temperate swards. Similarly leaf bulk densities are markedly lower, particularly in the uppermost layers of the sward and consequently it is difficult for animals to prehend large quantities of leaf in each bite from these swards. High sward bulk density, a low stem content and a high leaf/height ratio have the major influence upon the size of bite taken by grazing animals (Stobbs 1973b). Feeding behaviour studies suggest that animal production can be improved by:—

1. Selecting leafy pasture plants which are easily harvested
2. Fertilizing pastures to produce dense leafy swards
3. Grazing management practices which maintain swards as near as possible to optimum for easy defoliation.

The canopy structure of swards which are continually being cut are usually less dense in the base and have quite different structure compared with grazing swards (Stobbs unpublished data) so great care is needed extrapolating from cutting experiments to the grazing situation. Similarly the canopy structure of spaced plants and seedling growth is different to regrowth cuts.

The energy required to pluck leaf from even the toughest plants is an insignificant part of maintenance requirements (Evans 1967) although movements in harvesting feed can involve considerable energy expenditure (Osuji 1974). Tensile strength of a leaf (break per unit dry weight) is positively correlated to cellulose and sclerenchyma content and measurements could give a guide to breakdown of herbage as well as indicating plant parts which can most easily be harvested by the grazing animal.

Rumination bites provide a useful guide to the fibrosity of the feed selected. Long rumination times are recorded with poor quality fibrous feeds and short rumination times with high quality feeds fed at the same level (Balch 1971) and together with rumination time/grazing time ratios can be related to herbage quality. Under grazing, animals tend to select a high quality less fibrous diet and ruminate less than when fed cut or chaffed feed indoors (Stobbs 1974c).

Grazing behaviour

Cattle graze tropical pastures for a longer time each day than temperate pastures even when large quantities of herbage are available for grazing (Stobbs 1974c). Under conditions where leafy material is difficult to harvest, cows compensate for the small size of bite eaten (Stobbs 1973a) by increasing the time spent grazing and also by increasing the number of bites taken (Stobbs 1974b). Fatigue limits the time that can be spent grazing to about 720 min/24 hr and bites during grazing rarely exceed 36,000/24hr. Where feed is limited and where swards are very mature and leaf inaccessible the time spent grazing and the number of bites taken approach this limit and it is probable that cows have difficulty satisfying their feed requirements.

Grazing patterns follow closely the periods of daylight when the quantity and quality of feed is good but under adverse conditions cattle extend grazing into hours of darkness (Stobbs 1970) and high producing lactating cows can be identified by the extent of foraging during the night. Since more than 50% of grazing can occur between 6 p.m. and 6 a.m. it is highly desirable to have good night paddocks to obtain optimum production (Rees, Minson and Kerr, 1972). During inclement weather

grazing time is reduced but cows compensate for these shortages by increasing grazing in subsequent periods. *Bos indicus* cattle will forage during hot weather whereas *Bos taurus* cattle will seek shade (Lampkin, Quaterman and Kidner 1958).

On good quality dense pastures cattle travel about 2-3 km in each 24 hr the actual distance depending mainly on the size of paddock, feed availability and quality of feed (Larkin 1954). The distance travelled increases when quality of feed is low. Obviously excessive walking is undesirable and cattle should not have to travel more than 1 km to water otherwise grass is not utilised uniformly and animals spend too long walking. Under extensive range conditions it is not normally feasible to have watering places so close together. Watering places for cattle should be no more than 8 km apart on level or gently rolling country or 1.5 km apart on very rough land (Hafez 1969).

Since leaf is the major component of the diet of most grazing animals and has a higher nutritional value it is suggested that more attention is given to the leaf component of the sward rather than to total dry matter yield. Studies of net assimilation and senescence of leaves within grazed tropical pasture swards could lead to a better understanding of pasture/animal relationships. The ultimate test of any index of the nutritional value of herbage is its relationship to animal performance and further testing of the effects of grazing behaviour upon animal productivity are required.

CONCLUSIONS

There are four factors limiting animal production from grazed tropical pastures; the growth of grass and legume, the nutritive value of herbage, intake per animal and harvesting by the animal. These factors are closely interrelated and in the field it is difficult to separate the relative importance of each.

Although the principles of nutrition, obtained under controlled animal house conditions, apply in the field, a dynamic situation exists under grazing conditions. The potential for selection is greater when animals graze tropical pasture swards than when grazing temperate pasture swards and the diet chosen can be of superior or inferior nutritional value compared with cut swards depending upon the degree of defoliation. A basic understanding of the processes involved in defoliation are required to evolve pasture species and grazing management systems which will improve animal performance. Because of the constantly changing nutritional value of the sward, techniques are required to measure animal performance over short time intervals.

Many tropical pasture swards have a canopy structure which causes the grazing animal to have difficulty in harvesting leaf. Availability and accessibility of leaf are the major factors influencing the quantity and quality of feed consumed by grazing cattle. Three-dimensional sampling of pasture is necessary to understand the feeding behaviour of grazing animals.

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