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DIET SELECTION

A CRITICAL EVALUATION OF THE ALKANE TECHNIQUE

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Introduction

In 1991/92 the gross value of the output from ruminants in South Africa amounted to more than R6 billion. This income has its origins largely in the interaction between the ruminant and the rangeland or cultivated pasture which it utilizes. Knowledge of plant/ruminant interactions, however, is seriously limited by a lack of suitable methods to determine accurately animal dry matter intake and the degree of selection by the animal of specific plant species in mixed pastures.

One of the most promising new methods for estimating plant selection and dry matter intake is the alkane technique developed by Mayes in Scotland and Dove in Australia (Mayes *et al.* 1986; Dove & Mayes 1991). The method is based on the use of alkanes as natural indigestible markers. Over the past ten years steady progress has been made, mainly in Australia and Ireland, in streamlining the procedure. The procedure has now also received wider international status in that Mayes and Dove have been invited to present a paper on the technique at the International Symposium on the Nutrition of Herbivores, in France in 1995.

The concept of using alkanes as markers

Plant alkanes are simple straight-chain hydrocarbons with carbon-chain lengths ranging from C_{25} (pentacosane) to C_{35} (pentatriacontane). They are components of the cuticular wax layer covering all higher plants and occur in plant material mainly as odd-chain molecules. Since alkanes are largely indigestible they are excreted in the faeces of herbivores and can be quantitated by means of gas chromatography. Their stability in the digestive tract of the ruminant appears to be related to the size of the molecule. The recovery in the faeces of dotriacontane (C_{32} alkane) is about 87%, while that of pentatriacontane has been estimated at 95%. Individual alkane concentrations vary among plant species, giving each species a characteristic alkane profile.

By determining the alkane composition of the individual plant species in a mixed pasture and the composition in a representative sample of the fodder selected by the animal, or in the faeces of the grazing animal, the proportions in which the different species are consumed can be estimated. In these estimates total intake remains unknown.

If faeces samples are used, a correction has to be made for the incomplete recovery of alkanes in the faeces. This can be done by dosing a sub-group of experimental animals with a mixture of even-chain alkanes and calculating their recoveries from their faecal levels. The recoveries of the natural odd-chain alkanes can then be estimated from a plot of faecal recoveries of the dosed alkanes against their carbon-chain lengths. The dosing of an even-chain alkane also permits the quantification of intake using the equation:

$$\text{Intake (kg/day)} = a/b \bullet c/d \text{ - - - - - } (1)$$

where a = external marker dose (mg/day)
b = external marker concentration in faeces (mg/kg DM) after correcting for the amount of external marker alkane naturally present in the forage.
c = internal marker concentration in faeces (mg/kg DM).
d = internal marker concentration in forage (mg/kg DM).

If the total intake and the proportions of each plant species in the intake are known, the intake of each species can be quantified.

Advantages of alkanes as markers

Alkanes have many advantages over most other indigestible markers used for intake studies. Advantages include:

1. Intake estimates are not dependent on *in vitro* digestibility determinations. Odd-chain alkanes are used as natural internal markers to calculate feed digestibility. The method automatically takes into account differing herbage digestibilities in individual animals as a result of different levels of intake, supplementary feeding or parasite burden.
2. Suitable external markers. Even-chain alkanes, which only occur in small amounts in plants, can be used as external markers for dry matter intake estimations. The procedure allows for the use of several internal and external markers which could be all extracted and quantitated in a single assay.
3. Quantitative recovery of external markers in the faeces is not essential. Intake estimates using alkanes as markers depend on the ratio of dosed external marker and natural internal marker. However, the recoveries of the dosed and natural alkane pair are so similar that any errors arising from incomplete recovery are cancelled out.
4. Ease of assay. The extraction, purification and quantitative separation of alkanes on a gas chromatograph is relatively simple.
5. Estimation of diet selection. The characteristic alkane profile of different plant species can be used to estimate diet selection by the grazing animal.
6. Dry matter intake and diet selection are estimated on an individual animal basis. Different types of animals, or animals receiving different supplements, could be studied simultaneously on a single pasture or rangeland.

Factors affecting the accuracy of the procedure

Administration of external marker

Synthetic alkanes have been dosed on a daily or twice-daily basis in the form of alkane-impregnated paper pellets (Mayes *et al.* 1986), or as alkane-impregnated cellulose powder in gelatin capsules (Vulich *et al.* 1991). A method of dosing alkanes in suspension-form has been developed in the Cedara laboratory. The form in which the marker is administered does not appear to affect the results.

Although once-daily dosing has been used in many studies, Dove *et al.* (1991) pointed out that faecal marker concentrations could be erratic. Twice-daily dosing, however, could disturb the normal grazing pattern of the experimental animals and makes the procedure more labour intensive. More research is required to establish the most suitable procedure for sheep and cattle. Most of the problems associated with the dosing of external alkane markers could be eliminated by making use of intra-ruminal controlled release devices. Controlled release devices for alkane delivery have been successfully tested on sheep (Dove *et al.* 1991). A controlled release device for alkane delivery to cattle is also being developed.

Faecal concentrations of dosed alkanes reach an equilibrium after 5 to 6 days. An adaptation period of 6 days is therefore essential in all studies involving the use of external alkane markers.

Sampling of herbage and faeces

Implicit in the use of the alkane procedure for estimating diet composition is the assumption that all the species grazed by the animal will be taken into account in calculating composition. The inclusion of species not grazed by the animal, or the omission of a species which has been consumed, could affect the accuracy of selection estimations. Cultivated pastures consisting of two or three species usually present no problems, but in the rangeland situation, where many species are involved, the recognition of species grazed could be more difficult. Additional knowledge on the palatability of the species involved and careful field observations while conducting the trial might be necessary to recognize selected species.

A prerequisite for precise selection estimations is the collection and analysis of representative samples of the individual herbage species involved, and the herbage selected by the grazing animal or the faeces of the animal. Dove *et al.* (1993) suggested that, once accustomed to a new pasture, oesophageal fistulated sheep can select in a single grazing a diet similar to that which they would consume over a more extended period. This might not apply to all types of pastures. Vulich *et al.* (1993), assessing the magnitude of sampling variation in alkane concentrations in a *Lolium perenne* pasture containing some *Trifolium repens* and other grasses, stressed the importance of sampling throughout the experimental period in order to obtain reliable estimations. However, no significant differences were detected in the alkane concentrations among samples obtained by clipping, hand plucking and those based on pooled oesophageal extrusa. It is generally conceded that oesophageal extrusa can provide useful information about the consumed herbage, but it is nevertheless a sample collected by a surgically-prepared animal over a relatively short period of 15-30 minutes. The herbage selected by the test animal over a longer grazing period could be different. This limitation can largely be overcome by regularly sampling extrusa by means of remote-control oesophageal valves.

Freeze-drying of samples is recommended in species selection and intake studies. A reduction in recovery of alkanes as a result of oven-drying has been reported and has been attributed to an increased difficulty in extraction (Dove & Mayes 1991). Sample preparation would be simplified if freeze-drying could be replaced by oven-drying. Effects of different drying temperatures and their interaction with sample type need urgent further research.

Analytical procedure

Alkanes are extracted from plant and faecal samples by means of nonpolar organic solvents such as petroleum ether or hexane, or by direct saponification in alcoholic potassium hydroxide (Dillon & Stakelum 1990). After solvent extraction or saponification, extracts are passed through a silica gel column to remove plant pigments and other impurities, leaving alkanes in the eluate (Mayes *et al.* 1986). The purified alkanes are separated and quantitated by means of gas chromatography, using a megabore column and flame ionization detector.

In order to simplify the quantitative extraction and purification of samples, a known amount of an alkane not present in the sample is added to the original sample as internal standard. Dove & Mayes (1991) recommend using tetratriacontane (C_{34} alkane) as internal standard, but the present author has found that many forage species contain considerable amounts of tetratriacontane and he therefore uses hexatriacontane (C_{36} alkane), which is usually absent from forage species.

By using an internal standard, a high degree of analytical precision is only required when initially weighing out the sample and when adding the internal standard. Originally the internal standard was dissolved in n-heptane, but it is now recommended that it is dissolved in less-volatile n-undecane to reduce to a minimum any changes in mass. The appropriate amount of internal standard is then dispensed on a mass basis.

A potential source of error is the use of alkane-contaminated glassware. Being water-insoluble waxes, alkanes are not readily removed from glassware by washing with water and detergents. Special precautions should be taken when using glassware which have been used for preparing capsules, pellets or alkane-coated grass for use as external markers. The alkane content of these preparations is about 1000 times that of forages and could readily be a source of contamination. Alkane-coated grass or filter paper should also not be milled in the same mill that is used for milling forage or faecal samples. The use of Parafilm, an alkane-containing product, to seal flasks or test-tubes, should be avoided.

If the necessary precautions are taken, alkanes can be extracted and quantitated with a high degree of precision. Vulich & Hanrahan (1990) showed that duplicate extractions, with the resultant doubling of the number of extractions conducted, contributed little to the analytical precision. They suggested that more herbage samples should rather be included and more animals should be considered in trials.

Procedure for calculating results

Dry matter intake is readily estimated using equation (1). Botanical composition can be calculated by means of simultaneous equations (Dove 1992).

The number of species which can be separated by means of simultaneous equations is limited by the number of alkanes used in the estimate. Ideally the number of species separated should equal the number of alkanes. Six odd-chain alkanes per sample are routinely quantitated and usually occur in sufficient quantities for selection estimates.

Dove (personal communication) is investigating the use of canonical variates analysis to examine differences in alkane patterns, since analysis of variance, treating one variate at a time, is an inadequate way of expressing differences in alkane patterns.

Alkane composition of herbage

Casson *et al.* (1990) suggested that the forage species should contain sufficient amounts (> 50 mg/kg DM) of alkane for accurate estimates of dry matter intake. The mean discrepancy between estimated and known intakes of four reported validation studies has been 0.8%, while the maximum discrepancy has been only 1.7% (Dove & Mayes 1991).

Several studies showed that the alkane concentration within a plant can vary from one plant part to another and is also related to the developmental stage of the plant (Laredo *et al.* 1991). This will be a source of error in estimating diet composition if the herbage samples used for alkane analysis contain plant parts not consumed by the intact or oesophageal fistulated animal. This stresses the importance of ensuring that representative samples of intake are obtained, especially in studies on highly selective grazers.

Since the estimation of diet selection is based on the differences between species in their individual alkane content, the greater the differences in alkane pattern between species, the greater the sensitivity of the estimation. For greatest sensitivity the total alkane content of component species should also be similar. If one species in the mixture has a low total alkane content compared with the others, it will be estimated with low sensitivity since its alkanes will tend to be swamped by those of the others. Little can be done to circumvent this problem.

Conclusion

The alkane technique, which is now being applied on a routine basis in the field, provides an accurate means of estimating total dry matter intake on an individual animal basis, and the partitioning of the intake into component plant species, provided certain precautions are taken. These certain precautions include the accurate administration of external alkane markers, the collection of representative samples of forage consumed and faeces excreted, the accurate analysis of alkanes and a sound procedure for calculating results.

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FORAGING PREFERENCES AND DIET QUALITY OF LIVESTOCK INDIGENOUS TO DRY AREAS

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Abstract

The diet selected by free ranging ruminants, whether assessed by direct observation or by analyses of extrusa or faecal samples, is very much influenced by season and consequently herbage availability. The growing season has a greater standing crop and diversity of species following increased available moisture for plant growth. This increased herbage allowance plays a major role in determining preference by grazing ruminants. Equally important are the species and growth nature of the forage plants as well as their chemical composition and nutritive quality. In adaptation to the changing grazing conditions, free ranging ruminants adjust feeding strategies in search of plants high in nutrient content and digestibility of organic matter. Frequently and particularly for goats, this means spending more time in selecting high quality plants in times when herbage is scarce and low in quality. While grass is consumed readily by all livestock species in the growing season, browse is the preferred plant group in the intermediate and

non-green seasons. Differences in species preference rating for individual plants increases the equity of feed resource exploitation when multiple animal species are grazed together in dry areas.

Introduction

From an ecological standpoint, dry areas are regions characterised by high temperatures, low erratic or seasonal rainfall, marginal crop potential and high rangeland use. About 54% of sub-Saharan Africa is either arid or semi-arid (Winrock International 1992) and suitable only for extensive animal production. In the typically arid areas total annual rainfall rarely exceeds 500 mm while between 500 and 1000 mm fall in the semi-arid agroecological zone. The soils are shallow, low in organic matter and nutrients and coarse textured. The period in which plants can grow varies from less than 3 to around 6 months in a year. The vegetation is dominated by short annual grasses and legumes and scattered perennial shrubs and trees. It is sparse, frequently absent, low in productivity and when mature is very low in nutritive value.

Pastoralism based on communal grazing is the major system for utilizing land in areas receiving 500 - 750 mm annual rainfall; in the wetter parts cropping is often integrated with livestock production. It is estimated that arid and semi-arid sub-Saharan Africa contain approximately 84 million cattle, 70 million sheep, 93 million goats and 13 million camels or 55% of the ruminant livestock population of the area (Winrock International 1992).

The large animal population is testimony to the fact that animal production is sustainable in the dry areas. Adaptive mechanisms evolved over time have made this possible. For example, through selective grazing ruminants are able to consume diets of a higher nutritive value than that on offer. There are variations in the magnitude of such selection because of differences in local climate, soil fertility, plant species and animal management factors.

This paper will review dietary preferences of grazing ruminants with emphasis on Kenya.

The Kenya rangelands

The arid and semi-arid areas of Kenya cover approximately 80% (Ng'ethe 1993) to 88% (De Leeuw *et al.* 1991) of the country's land area and constitute the zones in which rangeland utilisation is the most common form of land use. They form part of the seven agro-climatic zones into which Kenya has been divided (Table 1). The basis of this division is moisture availability for plant growth expressed as the ratio of rainfall to open pan evaporation (r/E_0). Thus, the rangelands have indexes of less than 40% and a maximum mean annual rainfall of about 1000 mm (Table 1). About 90% of this land area is located below 1200 m and experience temperatures of between 22 and 40°C (De Leeuw *et al.* 1991).

The more recent percentage estimates presented by Nge'the (1993) put the animal distribution in the rangelands of Kenya at 8.5 million cattle and 15.4 million sheep and goats. Most of the wildlife and all the 0.8 m camels in the country are also found in the rangelands.

The vegetation in the dry areas consists of ephemeral grasses and herbs and perennial largely deciduous trees and shrubs. The genus *Acacia* is common in much of the rangelands. Forage productivity from the various plant species is very much influenced by variability in the rainfall between seasons and years.

Table 1 Rainfall distribution in the arid and semi-arid areas of Kenya[1]

Zone	Class	Annual rainfall (mm)	r/E_0 (%)
IV	Semi-humid to semi-arid	600 - 1000	40 - 50
V	Semi-arid	450 - 900	25 - 40
VI	Arid	300 - 550	15 - 25
VII	Very arid	150 - 350	< 15

[1]Modified after Ng'ethe (1993).

ILCA (1984) and Rutagwenda (1990) have estimated forage availability in the growing season to range from about 500 kg of dry matter (DM) per ha during periods of below average rainfall to about 2 tonnes DM per ha in high rainfall areas. Schwartz *et al.* (1988) have also reported that under the bimodal rainfall pattern of northern Kenya, medium density stands of *Duosperma eremophilum*, a common browse in the area, yielded approximately 2500 kg of forage (leaves, flowers, fruits and young shoots) per ha per year. When the forage is from perennial vegetation it remains green longer into the dry season than does ephemeral vegetation and that from woody plants is capable of persisting from season to season (Schwartz *et al.* 1988). The common plant genera grazed by cattle and camels in the arid lands of Kenya include *Aristida, Chloris, Chrysopogon, Eragrostis, Sporobolus, Tetrapogon, Pennisetum, Digitaria, Cenchrus, Grewia, Euphorbia, Salvadora, Maerua*, and *Balanites* (see Abate *et al* 1994). Qualitatively herbs, shrubs and tree litter have higher crude protein and mineral levels than found in grasses (Kayongo-Male 1986, Schultka & Schwartz 1987). Moreover the latter mature and lose quality so rapidly that for most of the year it is little digested and of sub-maintenance value.

Animal productivity in the range

Inspite of fluctuations in feed supply the traditional grazing practices in the Kenya rangelands have ensured livestock productivity coefficients comparable to those achieved under commercial ranching within the country and elsewhere in the tropics (Abate *et al.* 1994).

Indeed there are high performance genes within the range animal population. For example, preweaning average daily gains of up to 160 g for goats and up to 100 g for sheep are possible under pastoralist conditions (Table 2). Similarly in years of favourable rainfall cattle on range can gain about 35 kg per ha (ILCA 1986/87). While this may seem modest it represents an achievement when compared to the net losses of 15 kg per ha experienced in times of food deficit. Again depending on the condition of the range, a lactation yield of between 518 and 823 kg of milk is possible from cattle in pastoralist systems (Table 3).

ILCA (1986/87) has also estimated that annual milk offtakes in Kenya vary from 17 kg per ha in normal years to 10 kg per ha in times of drought.

Yields from camels are higher than those from cows and milk offtakes may vary from 1000 to 2500 kg over a lactation period of 12-18 months (Nicholson 1984). The ability of animals to survive and reproduce in the range is shown in Table 4.

Table 2 Growth parameters of Kenyan pastoral range livestock[1]

Livestock	Birth weight (kg)	Pre-weaning ADG (kg)	Mature weight (kg)
Cattle	11.0 - 18.0	0.12 - 0.19	186 - 480
Goats	1.6 - 2.5	0.03 - 0.15	17 - 70
Sheep	1.5 - 3.0	0.04 - 0.10	19 - 41
Camels	23.0 - 41.0	0.31 - 0.60	294 - 700

[1]Modified from Abate *et al.* (1994)

Table 3 Lactation related parameters of Kenyan pastoral range livestock[1]

Livestock	Milk yield (Kg/d)	Days in milk (d)	Yield/fluctuation (Kg)
Cattle	-	180 - 210	518 - 823
Goats	0.05 - 0.65	60 - 180	9 - 110
Sheep	0.05 - 0.27	90 - 181	10 - 29
Camels	1.60 - 3.0	285 - 500	627 - 1592

[1]Modified from Abate *et al.* (1994); (-) Data not available

Table 4 Reproductive and survival parameters of Kenyan pastoral range livestock[1]

Livestock	Age at 1st parturition (mo)	Parturition interval (d)	Survival rate (%)
Cattle	34	489 - 569	84 - 99
Goats	13 - 27	227 - 461	55 - 94
Sheep	13 - 24	192 - 358	70 - 94
Camels	27 - 74	418 - 898	73 - 93

[1]Modified from Abate *et al.* (1994)

These values are similar to those in Ethiopian and Australian ranches where conditions are better. There seems, therefore, little scope for improvement of performance in terms of reproduction and survival rates; but evolution into ranching or improvement in management techniques may sustain high and frequent offtakes of milk and meat per ha (Abate *et al.* 1994).

Feeding preferences in rangelands

Feeding preferences and diet selection by range livestock are dependent on the biomass productivity of the range which is seasonal because it is closely associated with the highly variable rainfall. Other factors which determine magnitude of selection include the species, age and quality of the herbage, species of animal and the stocking rates and, therefore, grazing pressure imposed upon the grazed plant communities. Equally important are those factors intrinsic to the animal. The use of rainfall records to define seasons into wet and dry as is done in many diet selection studies (for example Sibanda 1984; Shaabani *et al.* 1986; Mufandaedza 1989; Stuth & Kamau 1990) has been found unreliable. A suggestion has instead been made to use plants actually selected by animals as a way of characterizing seasons or the pasture condition available to animals (Schwartz 1987; Rutagwenda 1990). These indicator plants must be preferred by being observed in the diet of the animals and they should be equally or widely distributed in the study area. Forage conditions are then described as green if animals feed on the indicator plants for 20 or more times in an hour and dry if indicator plants are eaten less than 10 times per hour. An intermediate season is one in which animals feed between 10 and 20 times on indicator plants (Rutagwenda 1990). Similarly, Kassily (1991) classified seasons into green/growing or non-green/dry on the basis of vegetation characteristics and not rainfall data. The vegetation in a green/growing season consisted of scattered annual grasses and a herb layer on the ground with fresh green leaves on the shoots of plants. In the non-green season the ground was bare and most species had dry mature leaves (Kassily 1991).

Assessment of preference feeding

The methods used to determine forage preferences of grazing ruminants vary from visual observations and manual plucking of plant parts presumed eaten to obtaining faecal samples or extrusa samples from surgically prepared animals for analyses and subsequent identification of components using microscopic techniques. Working in a thornbush savannah of northern Kenya, Rutagwenda (1990) observed that in all seasons of the year dicots were preferred to monocots by goats. In another report, Rutagwenda *et al.* (1990) showed that like goats, camels spent more than 80 % of their total feeding time on dicotyledonous plants irrespective of season. Sheep on the other hand spent more time ($P \leq 0.001$) feeding on monocots than goats and camels in all the seasons (Table 5).
Working with similar methods Schwartz *et al.* (1988) reported that in north central Kenya, *Duosperma eremophilum*, was most preferred by free ranging goats during the growing seasons when biomass quality and quantity were also high. Kassily (1991) used the bite count technique to quantify forage selection by camels in an Acacia woodland and found that trees and tall shrubs made up 92.5% of the diet while low growing shrubs constituted 7.4% throughout the year. Preference for parts of plants was also shown with special liking for pods of *Acacia* and *Prosopis* species. Occasionally the animals avoided fresh leaves and picked out dry ones (Kassily 1991). Kibet (1986) too carried out observations on cattle in an *Acacia-Digitaria* grassland of eastern Kenya and showed that cattle preferred grass to either forbs or browse and selectively grazed succulent or tender parts of plants. While availability plays a major role in determining selection sometimes animals consumed other plants even in the presence of abundant preferred species. Cattle showed a high preference for green *Talinum kafrum* forb even though plenty of grass was growing beside the forb (Kibet 1986). Using samples from esophageally fistulated animals South & Kamau (1990) reported that grass and grasslike species were important in goat diets during the early dry season and this changed to browse, particularly *Acacia senegal* pods during the late dry season; in the early wet season forb consumption increased at the expense of grass and browse (Table 5). In the same study *Bothriochloa insculpta*, a species with high secondary compounds, was less preferred throughout the study period an observation that supports the depressing effects of high levels of such compounds on intake, digestibility and animal performance.

In Zimbabwe Mufandaedza (1989) used analyses of extrusa

Table 5 Seasonal variation in the foraging preference of livestock in dry areas[1]

Species	Study area	Assessment method	Preference	Season
Goats	Thornbush savannah	Direct observation	Dicots	All
Goats	Bushed Wooded grassland	Direct observation	Browse	Dry
Goats	Bushed Wooded grassland	Direct observation	Grass	Growing
Goats	Acacia senegal savannah	Oesophageal fistulated	Grass	Early dry
Goats	Acacia senegal savannah	Oesophageal fistulated	Acacia pods	Late dry
Goats	Acacia senegal savannah	Oesophageal fistulated	Forbs	Early wet
Sheep	Thornbush savannah	Direct observation	Monocots	All
Camels	Thornbush savannah	Direct observation	Dicots	All
Camels	Acacia woodland	Direct observation	Tree and tall shrubs	All
Cattle	Grass/Legume pasture	Oesophageal fistulated	Grass	Early growing
Cattle	Grass/Legume pasture	Oesophageal fistulated	Legumes	Mid to late growing
Cattle	Acacia-digitaria grassland	Direct observation	Grass	All
Cattle	Wooded and open grassland	Oesophageal fistulated	Grass	All

[1]Compiled by author from various sources

samples to conclude that cattle grazing a star grass-silverleaf desmodium pasture exhibited a clear pattern of diet preferences with season. There was predominance of grass in the early growing season and legume in the mid to late growing season (Table 5). Mnene & South (1985) further showed that in the dry season grass followed by woody species were the most dominant plants in the diets of cattle with leafy fractions being dominant in the diets selected.

Table 6 Seasonal variation in quality of diets selected by goats and sheep in a thorn-bush savanna[1]

Parameter	Quality of plants		
	High[2]	Medium	Low
Potential degradability, %	83.2 ± 7.1	69.4 ± 10.4	51.5 ± 16.0
Half life, hrs	10.2 ± 8.4	17.2 ± 2.0	28.8 ± 26.3
C	0.1 ± 0.05	0.09 ± 0.1	0.05 ± 0.05
Season when selection was highest	Green	Intermediate	Dry

[1]Modified from Rutagwenda (1990)

[2]Overall goats spent more time ($P<0.01$)selecting high quality plants than sheep

Nutritional characteristics of selected diets

In herbage of dry areas nutrient content is concentrated according to season with CP and mineral elements being highest in the early growing season and lowest at the end of the dry or non-green season. The seasonal variation in the protein content of *Acacia nilotica* foliage is between 10 and 23% (Lamprey *et al.* 1980). Dietary CP and digestibility of DM or organic matter (OM) increased gradually from the dry or non-green season and peaked in the wet or green season before dropping to a low in the subsequent dry or non-green season (South & Kamau 1989, Kassily 1990).

The reverse was true for the levels of detergent fibres and lignin (Kassily 1990). The digestibility of protein and OM of *Duosperma eremophilum* changed from between 60 and 80% during the growing period to around 40% in the dry or non-green season (Schwartz *et al.* 1988). These examples serve to point out that in the course of the year free ranging ruminants need to adapt to changes in nutritional quality of their diets.

Mnene & South (1986) reported that diets selected by goats during the wet season had nearly twice as much CP as those selected in the dry season. Fistulated steers grazing veld grass in Zimbabwe similarly selected diets in which the level of CP and potential degradability of DM and CP were 15.0, 73.4 and 85.8% respectively in the wet season and 5.3, 39.7 and 48.8% respectively in the dry season (Sibanda 1984). In experiments undertaken qualitative differences in the forage selected by sheep and goats were recorded by Rutagwenda (1990) in the dry, intermediate and green seasons.

During the green season when a lot of good quality plants were available, both species of animals selected high quality plant groups or those with a dry matter disappearance rate (DMDR) of over 70% at 48 hours incubation (Table 6).

More time was spent feeding on poor quality plants (DMDR below 50%) in the non-green season because of the generally low quality of many plants during this season. In the intermediate season all animals increased the proportion of time spent feeding on medium quality plants (DMDR between 50 and 70%). The time goats spent feeding on high quality plants was significantly ($P\leq0.01$) higher than in sheep leading to the conclusion that goats were superior to sheep in selection strategies (Rutagwenda 1990).

Table 7 Nutritive value of selected forages in relation to their frequency in vegetation[1]

Species	Ash	CP	NDF	IVDMD	Freq. in vegetation	% in diet
	(% DM)			(%)		
Euphorbia spp[2]	12.7	8.5	40.1	66.1	4.0	20.6
Salvadora persica	26.4	17.6	34.6	67.6	7.5	17.7
Boscia corriacea	9.1	18.6	52.2	61.6	15.5	8.9
Acacia tortilis	6.6	16.7	40.2	60.7	15.0	6.3
Prosopis chilensis[2]	8.8	15.0	44.7	56.0	1.0	3.8
Cordia sinesis	16.6	12.0	41.7	47.1	6.0	0.5

[1]Modified from Kassily (1990); [2]Planted species

In contrast Shaabani *et al.* (1986) showed that the digestibility of forage selected by steers in an open and bushed grassland in the dry season was about 64% and equal to that consumed in the transition period where new lush growth in both herbacious and browse species was available.

In the work of Kassily (1991) factors other than season seemed to have influenced dietary selection since most forage resources were perennials which persisted from season to season.

The contribution of individual species to the camel diet and the relative frequency in the vegetation community from which they were selected are presented in Table 7.

It was apparent that digestibility was highest for those plants that were selected most (Table 7). Less herbage would, however, lead to reduced selectivity and hence poor nutritive value of portions selected. Increased bush depressed total digestible energy intake of fistulated heifers especially during the dry season (Mnene & South 1986). It is recorded that only part of the consumable biomass from browse plants is actually consumed. Quite often only a small amount is accessible to animals either because the branches are too high or some of the leaves are concealed owing to the specific growth nature of the plants (see Abate 1993). For situations of less available herbage or where selection capabilities are poor, animals would need to optimise utilization of low quality forages through development of efficient mechanisms of digestion.

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