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Seasonal diet preference of cattle, sheep and goats grazing on the communal grazing rangeland in the Central District of Botswana

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Diet composition, forage preference and diet overlap among of goats, sheep and cattle grazing on communal rangeland in the Central District of Botswana were evaluated to determine the potential for forage competition to provide better ideas for managing these rangelands. Diets and forage preference were determined through microhistological faecal analysis. Animal faeces and reference plant material of the study area were collected, ground to fine particles and prepared into slides of which histological features of each animal species were studied under the microscope. Features on the faecal sample slides were matched with those in the reference plant material. Estimates of forage biomass and quality were estimated along transects and species composition was determined using a wheel-point apparatus. Season was a major factor affecting herbage biomass and quality. Forage quality decreased from wet to dry season with greater decreases in grass than browse. The content of nitrogen was higher in browse than in herbage in both seasons, and the seasonal decline in browse was less than in herbage. Cattle and sheep diets constituted mostly grasses, but cattle do browse as well during the dry periods. Goats selectively concentrate on browse all the year-long and were more diverse in their diet composition than either cattle or sheep, giving the former better chances of standing harsh conditions. Preferred plant species were not the necessarily the most common on the range. Therefore, monitoring productivity and use of key forage species, particularly of grasses, should complement management objectives.Diets overlaps were generally high during dry seasons, reflected seasonal influence as animals shift diets focus, when the potentials of forage selections are restricted to limited species diversity and availability. The results suggest potential for forage competition between cattle and sheep is highest during dry seasons for grasses.

Key words: Browse, forage availability, species diversity, diet overlap, forage species selection, forage species preference.

INTRODUCTION

Research on the pattern of diet selection requires an understanding of the forage and nutritional needs of

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range animals and competitive interactions among them. Diet selection in terms of both quantity and quality is primarily a function of the types and amount of feed on offer (Pieper, 1978). Selective grazing, due to differences in relative plant palatability, is a problem confronting people concerned with the practices of correct range utilization. Two forms of selective grazing, namely species selective grazing and area selective grazing were identified (Bailey, 1995; Soder et al., 2009; Masahiko et al., 2008). The causes for differences in palatability among both grasses and other life forms are as yet not clearly understood in spite of the fact that numerous attempts had been made in the past to relate preference differences to a number of factors such as forage quality (Bailey, 1995; Van Dyne and Heady, 1965; O'Reagain and Mentis, 1989; Soder et al., 2009), frequency of grazing and forage available in the range (Gammon and Roberts, 1978; Darlene et al., 2005; Kilonzo et al., 2005).

The measurement of animal diet preferences presents numerous problems that, as yet, have not been entirely overcome. Therefore no standard method has been devised by which animal preference can be successfully measured under a variety of conditions has been devised. The faecal technique is increasingly advocated to avoid the disadvantages of other methods for developing diet of free- ranging ruminants (Sparks and Malcheck, 1968; Smith and Shandruk, 1979; Kilonzo et al., 2005; Soder et al. 2009). This method examines and depends on the identification of indigestible cutinised fragments of leaves persisting in the faeces (Storr, 1961; Sparks and Malcheck, 1968; Liversidge, 1970; Scotcher, 1979; Holechek and Gross, 1982; Kilonzo et al., 2005; Soder et al., 2009). However, the epidermal tissues of forbs were not as easily found in cattle and sheep faeces (Free et al., 1970). Also during the growing season the faecal analysis method tend to under-estimate the forbs and over-estimate the grasses (Vavra et al., 1978) in the diet when compared to fistula technique. In winter, however, the two methods were found to be comparable. Most scientists however, agree that differential digestion of plant species has little or no influence on the proportion of identifiable plant fragments (Free et al. 1970; Anthony and Smith 1974; Dearden et al., 1975; Alipayo et al., 1992; Kilonzo et al., 2005; Soder et al., 2009). Diet composition data alone are not sufficient to explaining the reason for observed diet differences between animal species, or switching of diet through the seasons. A knowledge of the reason why herbivores select the species that they eat is necessary for an understanding of the forage needs of range animals and the underlying basis of composition interaction among them (Hanley, 1982). Information on herbage availability and quality is therefore, also essential. Forage availability is necessary for determining stocking rates; determining changes in range condition and determining the responses to many other treatments (Pieper, 1978). The most widely used methods for estimating herbage availability include: a) clipping method (Mueller-Dombis and Ellenberg, 1974), b) indirect method (Cook and Stubbendieck, 1986; Jordaan et al., 1991; Pieper, 1978), c) weight estimate methods (Tadmor et al., 1975; Ahmed and Bonham, 1982; Pechanec and Pickford, 1937) and the content of alkane in the herbage Lou et al. (2004).

Variations in nutrient content occur between, and within, plant species and herbivores select their food to obtain a nutritionally balanced diet (Owen - Smith and Novellie, 1982; Hardy and Mentis, 1986; O'Reagain and Mentis, 1989; Hendricks et al., 2002; Kilonzo et al., 2005; Villalba and Provenza, 2009). Some grass species (e.g. *Panicum maximum*) are characterized by high levels of a particular element (e.g. nitrogen) and no single species can accumulate high levels of all nutrients (Pratchatt et al., 1977; Georgiadis and McNaughton, 1990; Villalba and Provenza, 2009). The variation in individual mineral concentrations, found among plant species may explain the observation that herbivores tend to diversify their diets (Bouttom et al., 1988). However, attempts to predict dietary selection on these bases in sheep (Westoby, 1974), kudu (Owen - Smith and Novellie, 1982), goats and impala (Cooper and Owen – Smith, 1985) have been unsuccessful. The latter proponents demonstrated that plant secondary metabolites (tannins) are important determinants of dietary selection among browsers.

Information on the diet preferences of large free roaming herbivores is an important tool in resource management. Such knowledge can be used in the assessment of nutrient intake of animals and evaluation of forage competition or complementary between herbivores (Holechek and Gross, 1982; McInnis et al., 1983; Hendricks et al., 2002; Kilonzo et al., 2005; Lou et al., 2004; Soder et al., 2009). This research was aimed at evaluating goats, sheep and cattle diet composition, diet overlap, and forage preference on communal grazing rangeland in Central District of Botswana to understand potential for forage competition to provide better ideas for managing these rangelands.

MATERIALS AND METHODS

Description of study area

The study was located at Makhi communal grazing area in the Central District of Botswana (approximately 26.10' degrees South and 23.40' degrees East at an elevation of 1200 m). The area is broadly described as a rolling flat country with flat dunes, wide plain depressions and pans (Weare and Yalala, 1971). The soils are classified as Ferralic arenosols (FAO, 1990). These are described as deep to very deep, well to somewhat excessively drained. The texture is fine sand to loamy fine sand and run–off is non – existent.

The region consists of sandveld vegetation type (Weare and Yalala, 1971) of the Northern Kalahari tree and bush savanna. The main tree species are *Terminalia sericea*, *Acacia fleckii, A. luederitzii,* and *Ochna pulcra*. Low growing shrubs, between taller trees, which often contribute significantly to canopy cover, include *Grewia flava, G. retirnevis, Bauhinia petersiana, Dichrostachy's cinerea Mudulea sericea* and *Searsia tenuinervis*. The grass component has a low basal cover and consists mainly of *Stipagrostis uniplumis, Eragrostis lehmanniana, Schmidtia pappophoroides, Anthephora pubescens* (perennials) and *Urochloa trichorpus, Aristida congesta, A. graciliflora* and *Megaloprotachne albescense* (annuals). Various families of forbs are also found. The mean monthly maximum temperatures range from 32 degrees centigrade in December and January to 23 degrees centigrade in June to July. The corresponding minima are 18 and 4°C, respectively. Rainfall is erratic in total and distribution, with an annual long – term mean of 451 mm.

Botanical composition of the diet of livestock was determined by analysis of faecal material using the microhistological technique as described by Sparks and Malechek (1968) and Dearden (1975) and further developed by Holechek et al. (1982). Freshly dropped dung samples were collected at three different water points (boreholes) in the case of cattle, and from rectal samples in the case of sheep and goats. These animals were grazed around each water point in common grazing range of the communal land. One or two pellets from each individual goat or sheep and a small grab sample from each mound of cattle dung were taken. At least fifteen sub - samples were collected from each animal species at a time. Sub - samples of each animal species were composited into a single sample and about 70 g was kept for the final sample. Samples were collected over seven days within each season throughout the year. Samples for cattle were preserved immediately by adding an equal amount of coarse sodium chloride (Hansen et al., 1978) and air dried.

Plant materials that included only leaves of woody species, stem and leaves for herbaceous plants in the study area were collected for use as microhistological reference slides. Slides for each faecal sample or plant reference material were prepared following the procedure described by Holechek et al. (1982). The prepared slides were then placed in a rack and dried at 60°C for 48 h and stored. These were later studied under the microscope and drawings were prepared, showing the histological features of each plant species. Five slides per faecal sample were prepared for each animal species (cattle, sheep and goats) and two slides for each plant species for the reference plant material.

A microscope using 100X magnification was used to identify plant species based on the epidermal cell characteristics. At each location (field) on the slide, plant species present were recorded. Twenty fields were read from each of the five faecal slides, resulting into a total of 100 fields per animal species sample per season. The characteristics on diet sample slides were matched with those in the reference plant material. The percentage frequency of each identified plant species was converted to density of particles per microscope field (Dearden et al., 1975; Sparks and Malechek, 1968). The relative density of fragments was then obtained from the frequency figures. Botanical composition results from microhistology were used to simulate the diet for the period for each animal species.

Forage samples (biomass and quality) were collected at the same period as the faecal samples collection to simulate the animals' diets. Available biomass was estimated using double sampling method (weight estimate method). Samples were taken at five points along the transect radiating from water point. These points were located at 100, 500, 1500, 2500 and 4000 m from the water point. These points were replicated three times at each water point. A 50 m x 50 m permanent plot at each sample point was demarcated in which herbaceous plants were measured. Within each such plot, 20 quadrates of 0.5 m^2 were randomly located to estimate herbage biomass. The first four quadrates were visually estimated and the fifth quadrate was clipped so that the visually estimated mass could be adjusted by a regression technique. The clipped samples were bagged by species and fresh mass taken and again, re-weighed after oven dry. Sampling was repeated each season over one year. Forage samples for nutrient analysis were taken at the same location were biomass estimates occurred.

Herbaceous plant species composition in the range was determined using a wheel-point apparatus were 200 points were recorded within the 50 m x 50 m permanent plot.

Data analysis

Average percent frequency of occurrence of forage species was computed by dividing number of fields in which the species occurred in 125 and then multiply by 100. For examples, if number of fields in a species occurred in 25 out of 125 fields, the frequency of that species was:

$$F = (X/Y)\,100 = (25/125)100 = 20\%$$

Where X= # of fields in which the plant species occurred and Y = the total # of fields in 5 slides.

The density (D) of discerned fragment was then estimated from the frequency by the formula:

$$D = 1n\,(1-F/100).$$

Where 1n = natural logarithm and F = Frequency (%).

For a given frequency, a mean density of identified fragments of forage species per microscopic field was converted to a relative percent density (RD) by the formula:

$$RD_i = D^i/\sum^n{}_{J=1}D_j)\ 100$$

Where Di = the density of discerned fragments of forage species in the diet and $\sum D_j$ = the sum of the densities of discerned fragments of all forage species in the diet.

Plant species diversity was calculated to indicate the diet breadth, on the basis of Shannon-Wiener Function (Krebs 1989) formula:

$$H' = -\sum{}^n{}_{1=1}\,(p_i)(\log_e P_i)$$

Where p_i = the proportion (%) of total sample belonging to the i^{th} species in the diet and n = total number of resource states.

Plant species diversity index indicates variety and evenness of components in the diet. The index increases with an increasing number of species in the diet. High species diversity indices indicate that the animals do not rely on a few plant species for most of their diet, but feed on a broad spectrum. Animal species characterized by high species diversities are potentially better able to adapt their diet changes in plant composition (Wolda, 1981). H' was selected because it is independent of sample size. However, Wolda (1981) indicated that it was sensitive to changes of rare species in the community.

Food habit studies of more than one animal species usually compare diet overlaps between any combinations of two diets. Dung analyses for botanical composition can be used to estimate the appropriate amount of diet overlap between different animal species. Overlap between diets was calculated using Morisita's similarity index (Morisita, 1959).

$$C_\lambda = (2\sum n_{ij}\,n) / [(\lambda_1 + \lambda_2)\,N_j\,N_k]$$

Where C_λ = Morisita's index of diversity of similarity between samples j and k (eg. between cattle and sheep), n_{ij} n_{ik} = no. of individual of species i in sample j and sample k, $N_k = \sum n_{ik}$ = total no. of species in sample k (e.g. cattle), $N_j = \sum n_{ij}$ = total no. of species in sample j (e.g. sheep), $\lambda_1 = \sum^n [n_{ij\,(ij}\,(n_{ij} - 1) / N_j\,(N_j - 1)]$; $\lambda_2 = \sum^n [n_{ik\,(ij}\,(n_{ik} - 1) / N_k\,(N_k - 1]$.

A similarity index represents the percentage of the diet that is identical, or the percentage of the diet that is shared by two animal

Table 1. Mean biomass availability (gm^2) of individual plant species and group in each season over two years in the free range grazing area.

Plant species	Summer	Autumn	Winter	Spring	Mean
Grasses					
D. eri	29.47^{bc}	57.6^{a}	37.12^{b}	30.57^{bc}	38.74
E. leh	46.38^{ab}	58.27^{a}	49.63^{a}	32.09^{bc}	42.34
E. rig	36.32^{b}	58.3^{a}	57.78^{a}	45.06^{ab}	47.74
S. uni	68.41^{a}	87.77^{a}	67.28^{a}	49.84^{a}	68.34
S. pap	48.96^{ab}	67.4^{a}	51.83^{a}	27.18^{bc}	48.10
Misc grass	39.52^{b}	51.02^{a}	44.86^{ab}	43.39^{ab}	41.54
M. alb/U. tri	28.65^{b}	39.22^{b}	23.59^{bc}	0^{d}	20.24
D.aeg/E. afr	42.72^{b}	31.83^{b}	9.0^{d}	0^{d}	21.02
C.bie/I. dal	25.07^{b}	19.83^{c}	3.78^{d}	0^{d}	12.20
A. thu/T.ter	30.95^{b}	16.49^{c}	3.1^{d}	0^{d}	9.36
Misc forbs	21.79^{c}	25.15^{bc}	14.88^{c}	11.65^{cd}	15.84
Total	**418.24**	**512.85**	**364**	**239.76**	

Values between the seasons followed by the same superscript are not significantly different (>0.05).

species. Morisita's index was preferred over the other indices because it is independent of sample size and species diversity (Wolda, 1981) and it shows potential for forage competition between animal species.

Relative preference indices (RPI's) for different plant species by different animals were determined using Krueger's (1972) formula:

RPI = % frequency in the diet composition / % frequency on the range composition.

Following calculations of RD's and C_λ, the main effects of seasons and animals were determined using GLM procedure SAS/STAT (2008). Where significant differences occurred, scheffe's test was used to separate the means.

RESULTS

Seasonal forage availability

Herbage available on individual plant species observed during study period is illustrated in Table 1. Comparison of different seasons revealed differences in the total available biomass of all species for each season. Significantly (P<0.05) low biomass was evident during spring and high (P<0.05) biomass peaked in autumn. The available biomass of annual grasses were very low (P<0.05) during the winter following the dry weather which resulted in their disappearance during the dry season (winter and spring). Their biomass diminished starting from autumn due to the physiological nature where leaf senescence occurred followed by death of the plant. Miscellaneous grasses and forbs were somehow uniformly distributed between the seasons.

Grasses: *D.aeg = Dactylotium aegyptium, D. eri = Digitaria eriantha, E. leh = Eragrostis lehmanniana, E. rig = Eragrostis rigidior, E. afr = Eleusine Africana, M. alb = Megaloprotachne albescens, S. pap = Schmidtia papophoroides, S. uni = Stipagrostis uniplumis, U. tri = Urochloa trichopus.*

Miscellaneous grasses: *A. con = Aristida congesta, A. gra = Aristida graciliflora,E. pal = Eragrostis pallens, P, pat = Perotts patens, P. squ = Pogonarthra squarrosa, M rep = Melinis repens.*

Forbs*: A. thu = Amaranthus thumbergii, C. bie = Cassia biescensis, I. dal = Idingofera daleoides, T.ter = Tribolus terrestris.*

Most of the available biomass was contributed by perennial grasses such as *S. uniplumis, E. rigidior, E. lehmanniana, D. eriantha* and *S. pappophoroides*. The mean biomass of forbs was 11% of total grass production. However, in summer, forbs increased to about 23% production of grasses component. Dry matter content was influenced primarily by stage of growth.

Crude protein, phosphorus and fibre of individual plant species were determined to indicate whether herbivores were exposed to a steady nutrition supply in the forage across the seasons. Seasonal variation in crude protein, phosphorus and fibre of individual plant species found in the communal grazing area is illustrated in Table 2. Nutrient content in forage species varied between species and seasons (stage of maturity). Significantly (P<0.05) higher levels of crude protein, phosphorus and lower fibre content occurred in summer for all plant species and the opposite was observed in winter. Almost more than 7% crude protein was generally present in the herbage during the growing seasons, but as low as 4% during the dormant season. Annual grasses and forbs had high level of protein during the growing period but foliage of forbs got shattered off during dry period. Their crude protein and phosphorus content declined after

Table 2. Seasonal concentration in crude protein (%). phosphorus (ppm) and fibre (%) of plant species occurring in forage.

	Season											
	Summer			Autumn			Winter			Spring		
Grasses	**Protein**	**Phos**	**Fibre**	**Protein**	**Phos**	**Fibre**	**Protein**	**Phos**	**Fibre**	**Protein**	**Phos**	**Fibre**
D. eri	7.73	0.063	34.11	4.39	0.036	35.71	4.06	0.036	35.86	4.61	0.047	35.80
E. leh	6.04	0.052	34.82	4.05	0.040	34.73	3.83	0.037	36.46	4.55	0.048	36.85
E. rig	5.67	0.057	32.98	4.06	0.043	33.36	4.12	0.044	33.02	4.02	0.049	35.65
S. pap	4.98	0.073	36.21	3.72	0.041	38.26	3.55	0.035	38.71	4.27	0.044	37.30
S. uni	5.66	0.061	37.02	3.98	0.043	38.90	3.17	0.034	38.72	4.49	0.047	41.17
P. max	8.03	0.081	34.00	6.80	0.055	37.06	5.21	0.071	34.92	5.59	0.076	34.34
U. tri	9.13	0.110	30.85	5.38	0.048	32.46	5.42	0.049	35.28	4.89	0.052	35.55
M. alb	7.81	0.072	25.55	3.58	0.040	32.89	3.86	0.043	31.49	3.32	0.041	32.55
E.afr	13.67	0.209	30.21	6.07	0.068	33.41	-	-	-	-	-	-
D.aeg	15.16	0.225	29.89	9.34	0.087	30.23	-	-	-	-	-	-
Aristida spp	4.67	0.062	40.94	3.24	0.042	40.31	3.31	0.039	43.03	2.86	0.022	42.36
Forbs												
A. thu	11.69	0.289	21.70	11.2	0.217	25.0	-	-	-	-	-	-
C. bei	13.71	0.192	23.09	8.61	0.195	29.01	-	-	-	-	-	-
I. dal	16.41	0.095	23.81	6.92	0.044	30.10	-	-	-	-	-	-
T.ter	13.11	0.283	25.60	11.77	0.213	26.70	-	-	-	-	-	-
Mean	**9.56**	**0.123**	**30.75**	**6.22**	**0.082**	**33.19**	**4.06**	**0.049**	**36.39**	**4.29**	**0.053**	**36.84**
Std Dev	**±4.02**	**± 0.01**	**± 0.42**	**± 0.90**	**± 0**	**± 5.37**	**± 0.01**	**± 0.01**	**± .02**	**± 0.16**	**± 0.01**	**± 0 .78**
Woody Plants												
A. fleckii	22.82	0.182	21.7	12.56	0.130	22.32	12.83	0.082	25.97	17.80	0.110	19.56
A. gerrardii	18.15	0.120	20.90	17.04	0.098	23.26	13.56	0.074	25.44	-	-	-
B. albitrunca	18.15	0.181	19.3	18.44	0.132	22.94	14.87	0.093	22.81	17.20	0.165	21.42
B. pertersiana	21.72	0.170	22.5	16.63	0.126	26.33	10.71	0.112	28.38	18.31	0.162	19.21
C. gratissmus	17.74	0.174	20.5	13.77	0.143	24.52	9.62	0.095	28.92	-	-	-
D. cinerea	19.44	0.140	20.3	14.72	0.128	25.31	10.30	0.114	27.62	-	-	-
G. flava	15.70	0.181	15.2	14.57	0.136	28.41	9.51	0.097	29.28	16.8	0.163	21.47
O. pulcra	11.96	0.113	29.3	11.65	0.098	29.97	9.11	0.067	30.81	15.40	0.185	19.55
M. sericea	17.18	0.144	28.2	16.14	0.122	28.95	-	-	-	-	-	-
T. ericea	14.13	0.108	15.7	15.64	0.079	24.97	15.60	0.039	29.11	16.30	0.133	16.83
Z. mucronata	13.22	0.123	23.5	14.81	0.076	23.75	-	-	-	-	-	-
Mean	**17.29**	**0.148**	**21.6**	**15.08**	**0.110**	**25.52**	**11.79**	**0.07**	**27.59**	**16.97**	**0.150**	**19.67**
Std Dev	**± .54**	**± 0.01**	**± 0.32**	**± 0.70**	**± 0**	**± 4.33**	**± 0.01**	**± 0.01**	**± 0.22**	**±0 .01**	**± 0.01**	**± 0.02**

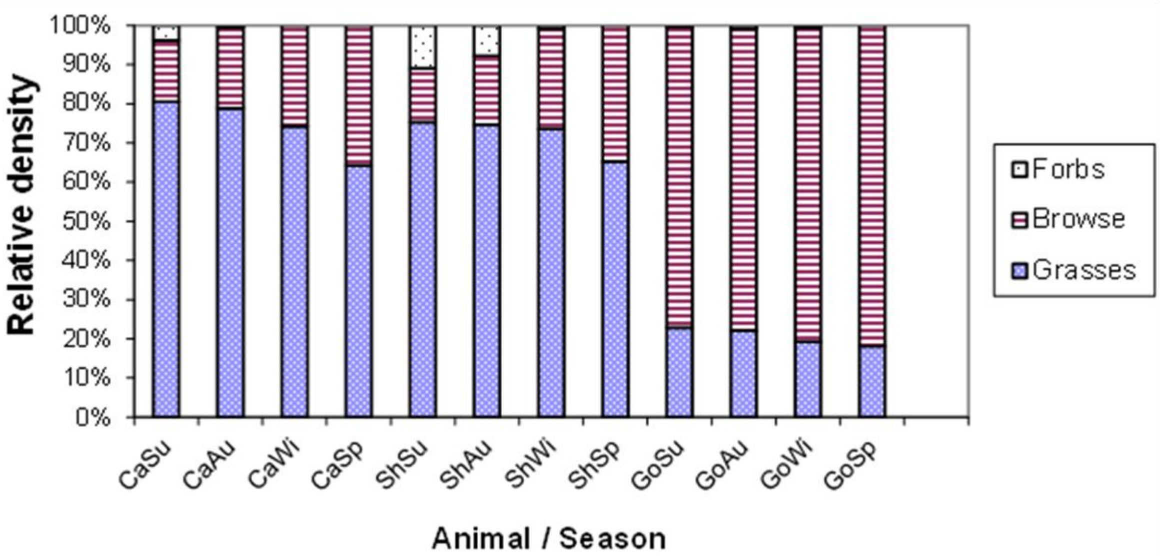

Figure 1. Average seasonal plant species class distribution between diets of cattle, sheep and goats in free ranging conditions. Key to animal / season: Ca = cattle, Sh = sheep, Go = goats, Su = summer, Au = autumn, Wi = winter and Sp = spring.

autumn to its minimum in winter.

Phosphorus content was more than two times as great in summer season as in winter. Grasses of *Aristida* spp had a very low crude protein or phosphorus content and the highest fibre content of all annual grass species during all seasons. Amongst the perennial grasses, the crude protein and phosphorus content of *D. eriantha* and *P. maximum* peaked to over 7 and 0.06%, respectively during summer and the fibre was as low as 34% (Table 2). Of the perennial grasses, S*. uniplumis* had the highest fibre content in all seasons. *Cassia biensis* and *I. daleoides*, representing the perennial forb component, were very high in both crude protein and phosphorus and low in fibre content but that their foliage shattered at the end of the autumn season due to leaf senescence and finally death of the above ground stems. The browse eaten by livestock across the seasons was relatively high in crude protein (Table 2). Crude protein and phosphorus content were at their peak in summer period, and dropped to their minimum in winter but were still above 7%, a minimum crude protein required to maintain the livestock. Phosphorus level is generally low, ranging from 0.03% in winter to 0.18% in summer for certain species.

Diet composition of cattle

Seasonal diet compositions of cattle, sheep and goats are illustrated in Figure 1. A total of 25 plant species were found in the diet of cattle of which included 75% grass, 23% browse and 2% forbs (Figure 1). Seasonally, cattle diets were dominated by grass species. Nine grass species >1% relative density occurred in the diet of cattle throughout the year and eight browse species occurred in the dung samples during the wet and dry seasons. *D. cinerea* was observed only during the summer period. Forbs were insignificantly found in the dung. The dominant grasses occurring in the diet of cattle included *D. eriantha, U. trichopus, S. pappophoroides, E. lehmanniana, M. albescens, E. rigidior* and *S. uniplumis* and woody species included *G. flava. M. sericea, C. gratissmus, B. petersiana, B. albitrunca* and *A. gerrardii* (Table 3).

Diet composition of sheep

Diet of sheep consisted of twenty one plant species; of which 74% were grasses, 21% woody species and 5% forbs (Figure 1). The dominant grass species included *D. eriantha, S. pappophoroides, M. albescens, U.trichopus, E. lehmaniana* and major woody species were contributed by *G. flava, M. sericea, C. gratissimus* (Table 4). Higher amount of grass and forbs were found in the diet of sheep during the summer period than in spring. The relative densities of browse in sheep diet were low during wet seasons and higher during dry seasons. Relative density of forbs was low (5%) but higher than that found in cattle.

Diet composition of goats

The diet of goat was composed of 78% woody species, 20% grasses and 2% forbs (Figure 1). In summer, the diet was 72% browse and this increased to 82% in

Table 3. Average relative densities (%; mean ± SE) of plant species in seasonal diets of cattle in free range grazing.

Plant species	Summer	Autumn	Winter	Spring	Mean
Grasses					
A. congesta	0.3±0.2	2 ±0.1	0	0.1 ±0.1	0.15
A. graciliflora	0.3 ±0.1	0.1 ±0.1	0.3 ±0.1	0.4 ±02	0.28
D. aegyptium	0.3 ±0.3	0.4 ±0.1	0	0	0.18
D. eriantha	9.9 ±1.2	15.1 ±0.6	14.4 ±1.2	10.7 ±0.6	12.53
E. lehmanniana	9.3 ±0.4	10.2 ±1.2	9.9 ±0.7	8.7 ±0.7	9.53
E. pallens	0.8 ±0.1	0.3 ±0.1	0.2 ±0.1	0.2 ±0.1	0.38
E. rigidior	7.4 ±1.1	8.3 ±0.8	9.4 ±0.5	13.8 ±1.2	9.73
E. africana	1.9 ±0.1	0.7 ±0.1	0	0	0.56
M. albescens	12.7 ±1.3	11.0 +1.1	8.7 ±0.9	3.9 ±0.9	9.1
P. squarrosa	0.4 ±0.1	0	0	0	0.10
M. repens	0.9 ±0.1	0.4 ±0.1	0	0	0.31
S. uniplumis	7.8 ±0.5	9.3 ±1.4	10.8 ±0.6	13.3 ±1.8	10.3
S.pappophoroides	10.4 ±1.3	12.2 ±1.6	11.7 ±0.9	9.8 ±0.9	11.0
U. trichopus	13.9 ±1.2	10.7 ±0.9	6.3 ±0.7	3.6 ±0.7	8.6
Forbs					
C. beiscensis	1.3 ±0.1	0.5 ±0.1	0	0	0.45
S. cordifolia	0.2 ±0.1	0	0	0	0.05
T. terrestris	2.3 ±0.2	05 ±0.2	0	0	0.7
Woody plants					
B. albitrunca	2.6 ±0.4	3.1 ±0.2	4.3 ±0.4	6.1 ±0.2	4.0
B. petersiana	2.9 ±0.1	2.3 ±0.3	2.9 ±0.3	3.5 ±0.1	2.90
C. gratissimus	3.4 ±0.4	4.7 ±1.2	5.9 ±0.8	7.6 ±0.5	5.40
D. cinerea	0.4 ±0.1	0	0	0	0.10
G. flava	4.4 ±0.3	4.9 ±0.6	6.2 ±0.7	8.7 ±0.8	6.10
G. retinervis	*0.4 ±0.1*	*2.1 ±0.1*	*2.0 ±0.3*	*2.3 ±0.2*	*1.70*
M. sericea	*3.4 ±0.2*	*3.9 ±1.3*	*6.7 ±0.9*	*6.5 ±1.2*	*5.13*
T. sericea	0.1 ±0.1	0	0.1 ±0.1	0.8 ±0.1	0.25
Total	100	100	100	100	100

spring. Species of woody plants occurring in their diet included *G. flava, G. retinervis, M. sericea, C. gratissmus, D. cinerea, B. petersiana, B. albitrunca* and *A. gerrardii* (Table 5). The dominant grasses in their diet included *D. eriantha, E. lehmanniana, S. pappophoroides, U. trichopus* and *M. albescens.* Seasonally, the goats were found to concentrate on woody plants. Plant species composition of their diet tended to be similar throughout the year.

Plant species diversity in cattle, sheep and goat diets

Mean annual plant diversity for cattle, sheep and goats was 21.1% (Table 6). Seasonal species diversity was significantly ($P<0.05$) high in summer and low in spring. Seasonal mean plant species diversity for cattle, sheep and goats was 19.9, 20.8, and 22.5%, respectively.Diets of goats were highest in average species diversity and cattle were lowest. Plant species diversity in cattle, sheep and goats diet were higher during summer period and lower during spring.

Diet overlaps of cattle, sheep and goats in communal grazing range

Diet overlaps of any combination of two livestock species differed significantly ($P<0.05$) by season (Table 7). The overlaps ranged from high for combinations involving animals that share similar forage types (eg. cattle and sheep) to low for combinations involving different foraging habits (eg. cattle and goats). The overlap of diets was greatest during the dry periods (winter and spring) and

Table 4. Average relative densities (%; mean ± SE) of plant species in seasonal diet of sheep in free range grazing.

Plant species	Summer	Autumn	Winter	Spring	Mean
Grasses					
A. graciliflora	0.3 ±0.1	0.2 ±0.2	0.2 ±0.1	0.3 ±0.1	0.25
D. aegyptium	3.7 ±0.5	2.8 ±0.2	1.3 ±0.3	0	3.90
D. eriantha	13.1 ±1.0	13.8 ±0.6	11.9 ±0.8	10.6 ±0.6	12.35
E. lehmanniana	10.3 ±0.5	9.8 ±0.8	9.2 ±0.5	8.4 ±0.6	9.45
E. rigidior	6.7 ±1.3	8.4 ±0.5	8.4 ±0.6	9.3 ±0.7	8.20
Eragrostis spp.	0.9 ±0.1	0.8 ±0.1	0	0	0.43
M. albescens	13.0 ±0.7	11.2 ±0.4	12.7 ±0.6	6.9 ±1.3	10.95
M. repens	1.4 ±0.9	0.8 ±0.2	0	0	0.55
S. uniplumis	1.0 ±0.1	2.7 ±0.3	3.5 ±0.5	4.4 ±0.6	2.90
U. trichopus	16.3 ±1.2	13.4 ±1.1	12.5 ±0.7	7.8 ±0.9	12.50
S. pappophoroides	9.5 ±0.8	11.1 ±0.8	13.9 ±1.2	17.6 ±1.5	13.10
Forbs					
C. beinscensis	6.3 ±0.5	4.3 ±0.7	0.8 ±0.1	0	2.85
T. terrestris	4.7 ±1.4	3.4 ±0.8	0	0	2.0
Unidentified	0.2 ±0.1	0	0	0	0.05
Woody plants					
A. fleckii	0.2 ±0.1	0.4 ±0.1	0	0.5 ±0.1	0.28
A. gerrardii	0	0.8 ±0.3	1.4 ±0.8	3.4 ±0.2	1.40
B. albitrunca	1.5 ±0.4	1.8 ±0.4	2.8 ±0.4	4.5 ±0.4	2.65
B. petersiana	1.4 ±0.6	2.2 ±0.2	2.8 ±0.6	2.8 ±0.5	2.33
C. gratissimus	2.9 ±0.3	3.6 ±0.6	5.3 ±0.4	7.6 ±0.6	4.60
D. cinerea	1.2 ±0.2	1.6 ±0.4	2.1 ±0.1	2.8 ±0.2	1.93
G. flava	3.3 ±0.7	4.0 ±0.5	5.8 ±0.7	8.1 ±0.5	5.30
M. sericea	2.8 ±0.2	3.2 ±0.6	4.7 ±0.8	5.3 ±0.3	4.00
R. bravisponosum	0.5 ±0.1	0	0.7 ±0.1	0	0.30

lowest in during wet periods (summer and autumn) for each animal combination. The observed overlaps reflect seasonal influences as animals shift diets focus. Mean overlaps were highest during the dry period (40%) and lowest during the wet season (32%). Mean overlap was high for cattle vs sheep (52.2%) and lowest for cattle vs goats (16.65%)

Relative preference indices

Fifteen of the most frequently occurring herbaceous species in the diets of cattle, sheep and goats were compared with their respective frequencies of occurrence on the range to determine the individual species preference by the study animals (Table 8). Cattle preferred (RPI >2) five of the fifteen herbaceous species in the following order: *D. eriantha, S. pappophoroides, U. trichopus, M albescens* and *E. lehmanniana*. The relative preference order of sheep was *S. pappophoroides, D. eriantha, U. trichopus* and *E. lehmanniana*. Goats showed a weak preference (RPI 1 - <2) with the following order *S. pappophoroides, D. eriantha, U. trichopus* and *E. lehmanniana*. Therefore, the relative preference for cattle (grazer), sheep (mixed feeder) and goat (browser), showed the greatest potential competition for only four grasses (*D. eriantha, E. lehmanniana, S. pappophoroides* and *U. trichopus*). However, the relative preference indices of grasses found in goats tended to be low while the competition for the latter grasses tended to be high for cattle and sheep.

Eleven woody species were selected for comparison with their respective frequency on the range to determine ranks in the diets (Table 8). Competition for browse plant species tended to be less for cattle, sheep and goats compared to the grass component. In general, cattle and sheep tend to have a weak mean preference for browse species, however certain plants species had higher relative preference indices. Cattle and sheep preferred five browse species (*C. gratissimus, G. flava, M. sericea, B. albitrunca* and *B. petersiana).*Goat preferred seven of the browse species but browsed all but one of the ten

Table 5. Average relative densities (%; mean ± SE) of plant species in seasonal diet of goats in free ranging conditions.

Plant species / Grasses	Summer	Autumn	Winter	Spring	Mean
A. congesta	0.3 ±0.1	0.2 ±0.1	0	0	0.13
D. aegyptium	0.3 +0.2	0.3 ±0.2	0	0	0.15
D. eriantha	4.5 ±0.2	4.4 ±0.2	3.4 ±0.1	3.3 ±0.1	3.90
E. lehmanniana	3.5 ±0.4	3.2 ±0.3	2.7 ±0.3	2.3 ±0.3	2.93
E. pallens	0.5 ±0.3	0.7 ±0.2	0.3 ±0.1	0.4 ±0.2	0.48
E. rigidior	1.2 ±0.2	1.3 ±0.1	1.5 ±0.1	1.5 ±0.1	1.38
M. albescens	3.4 ±0.2	3.5 ±0.1	2.8 ±0.2	2.9 ±0.1	3.15
S. uniplumis	0.7 ±0.1	0.9 ±0.2	0.6 ±0.1	0.9 ±0.1	0.78
*U. tri*chopus	3.4 ±0.4	3.6 ±0.3	3.8 ±0.2	3.5 ±0.3	3.58
S. pappophoroides	4.1 ±0.5	4.0 ±0.4	4.0 ±0.2	3.8 ±0.4	3.98
Unidentified	0.2 ±0.1	0.3 ±0.1	0	0	0.13
Forbs					
I. *daleoides*	0.4 ±0.2	0.3 ±0.1	0	0	0.18
S. cordifolia	0.3 ±0.1	0.8 ±0.1	0.5 ±0.1	0	0.40
T. terrestris	0.6 ±0.3	0.3 ±0.1	0	0	0.23
Woody plants					
A. fleckii	0.5 +0.1	1.5 ±0.1	0.8 ±0.1	0	0.70
A. gerrardii	4.1 ±0.2	3.9 ±0.3	4.3 ±0.5	3.8 ±0.3	4.00
B. albitrunca	6.6 ±0.4	7.1 ±0.2	8.4 ±0.8	7.8 ±0.4	7.48
B. petersiana	11.3 ±0.9	11.7 ±0.3	9.7 ±0.3	8.4 ±0.4	10.28
C. gratissimus	10.9 ±1.2	12.7 ±0.9	13.5 ±0.6	15.9 ±0.6	13.25
D. cinerea	13.4 ±0.4	13.5 ±0.9	12.9 ±0.5	11.9 ±0.7	12.93
G. flava	12.2 ±0.6	13.6 ±1.4	14.3 ±0.3	16.6 ±1.1	14.18
G. retinervis	2.1 ±0.4	2.2 ±0.2	3.1 ±0.3	3.4 ±0.2	2.70
M. sericea	9.6 ±0.3	12.2 ±0.7	13.6 ±0.4	14.9 ±0.7	12.58
R. bravispinosum	0.6 ±0.1	0.7 ±0.1	0	0	0.33
T. sericea	0.2 ±0.1	0	0	0	0.05
Unidentified	0.4 ±0.2	0.6 ±0.2	0	1.0 ±0.6	0.5

Table 6. Average plant species diversities (%) of seasonal diets of cattle, sheep and goats in free ranging grazing conditions.

	Livestock-Type				
Season	**Cattle**	**Sheep**	**Goats**	**Mean**	
	Summer	22.4[a]	21.8[ab]	24.5[a]	22.9[a]
	Autumn	20.9[ab]	21.5[ab]	22.7[a]	21.7[ab]
	Winter	19.2[b]	21.2[ab]	22.9[a]	21.1[ab]
Spring	17.1[c]	18.7[b]	19.9[b]	18.6[b]	
Mean	19.9	20.8	22.5	21.1	

Means within each animal species followed by the same letter are not significantly (P>0.05) different.

species (Table 8). The mean relative preference index for browse by goats was more than three times that of cattle and sheep. The greatest relative preference index for any plant species (likely to compete for) was that by cattle, sheep and goats for *G. flava, C. gratissimus* and *B. albitrunca.*

DISCUSSION

The microhistological technique is a useful tool for estimating the botanical composition of livestock diets. As reported by Storr (1961); Free et al. (1970); Soder et al. (2009)*;* Kilonzo et al. (2005), the technique was also

Table 7. Seasonal diet overlaps (%) of cattle, sheep and goats in free ranging grazing conditions.

	SEASONS				
Animal	**Summer**	**Autumn**	**Winter**	**Spring**	**Mean**
Cattle vs sheep	47[b]	44.7[b]	59.3[a]	57.8[a]	52.2
Cattle vs goats	14.3[b]	16.3[b]	15.0[b]	21.0[a]	16.65
Sheep vs goats	38.1[a]	35.0[a]	37.0[a]	41.2[b]	37.5

Means between the seasons followed by the same letter are not significantly (P>0.05) different.

Table 8. Relative preference indices (RPI) of herbaceous and browse plant species occurring in cattle, sheep and goats diets for vegetation in free – range grazing.

Herbaceous spp.	**Cattle**	**Sheep**	**Goats**
A. congesta	0.1[d]	0[d]	0[d]
A. gaciliflora	0.3[d]	0[d]	0[d]
D. eagyptium	0.35[d]	0.21[d]	0[d]
D. eriantha	5.58[a]	3.74[b]	1.23[a]
E. lehmanniana	2.11[c]	2.21[bc]	1.02[a]
E. rigidior	1.7cd	1.51[c]	0.91[b]
M. albescens	2.6[bc]	1.75[c]	0.53[c]
P. squarrosa	0.01[d]	0[d]	0[d]
M. repens	0.03[d]	0[d]	0[d]
S. uniplumis	1.89[cd]	0.94[d]	0.50[c]
S. pappophoroides	4.02[b]	4.52[a]	1.38[a]
U. trichopus	3.4[b]	2.26b[c]	1.2[a]
C. beiscensis	0.01[d]	0.53[d]	0[d]
S. cordifolia	0[d]	0[d]	0.12[c]
T. terrestris	0.13[d]	0.10[d]	0[d]
Mean	**1.48**	**1.18**	**0.45**
Browse spp			
A. fleckii	0[d]	0.02[d]	1.20[c]
A. gerrardii	0.01[d]	0.02[d]	4.20[c]
B. albitrunca	2.87[a]	2.90[a]	6.71[b]
B. petersiana	0.91[a]	1.21[c]	3.01[d]
C. gratissimus	2.27[ab]	2.25[b]	8.68[a]
D. cinerea	0.01[d]	0.05[d]	4.71[c]
G. flava	2.93[a]	3.04[a]	6.90[b]
G. retinervis	0.05[d]	0[d]	1.05[e]
M. sericea	1.92[b]	1.40[c]	3.57[cd]
R. bravispinosum	0[d]	0.03[d]	0.91[e]
T. sericea	0.01[d]	0[d]	0[d]
Mean	**0.99**	**0.99**	**3.73**

Means within each animal species followed by the same letter are not significantly (P>0. 05) different.

found to under-estimates the epidermal tissues of forbs in the diet of livestock in this study. The study also revealed that high quality and more availability of forage during the growing period permitted animals to select a wider range of plant species with little or no risk of nutritional stress.

Seasonally, cattle diets were dominated by grasses.

This emphasized the feeding habit of cattle as mainly grass feeders. However, some plant species were utilized more than others. Animal foraging habits changed as the dormant seasons approach and shifted their diets to include woody plants because of the decline in herbaceous quality and loss of most of the ephemeral annual biomass. Villalba and Provenza (2009) stated that under natural conditions where plant diversity is the rule, not the exception, eating a variety of foods is how the animals meet their nutritional requirement.

More woody species occurring in livestock diet during the dry periods are in agreement with various workers (Le Houerou, 1980; Ramirez et al., 1993; Ngugi et al., 2004; Katjiua and Ward, 2006). Omphile (1997) reported that greater quantities found in the diets of buffalo and zebra during the dry seasons, reflect a period during which grass was less available in quantity and low in quality and animals may then supplement their diet from woody plants. The dominance of woody species in the diet of goats across the seasons confirms that this species is a browser (Le Houerou, 1980; Ramirez et al., 1993; Ngugi et al., 2004; Mkhize et al., 2014). The ability of selectively foraging on browse all the year round ensures them of continuous supply of a high quality diet (Omphile, 1997; Ngugi et al., 2004; Mkhize et al., 2014). Goats can withstand conditions were natural vegetation has degenerated because of overgrazing or bush encroachment while populations of grazers, such as cattle decline (Moleele, 1998), because goats probably exhibit an opportunistic feeding strategy (Le Houerou, 1980). While it is likely that the decline in quality of the available forage would negatively affect the nutritional status of the animals, it is not clear whether animals consciously select the most nutritious forages available in this study. Decrease in their N, P and increase their fibre content from wet to dry season appear to be related to maturity of current year's growth. A commonly used approach in livestock production is to supplement the deficient nutrients by feeding enhanced supplements if the natural forage does not meet the nutritional needs of the animals.

Cattle did not prefer plant species in order of availability, as the most highly ranked grasses in their diet were not the most available (g/m^2) on the range. For example, *S. pappophoroides*, one of the most highly preferred in the diet of cattle, was not only among the least common on the range, but also the least available in terms of biomass. On the other hand, *S. uniplumis*, one of the less preferred species was one of the most frequently occurring and most available (g/m^2) of all the herbaceous species throughout the year. These results concur with those revealed by Hu et al. (2014). Differences between the mean wet and dry season's biomass of annual grasses were primarily due to early cessation of growth and ultimate death of plants, which, coupled with grazing pressure, led to significant reduction in the average biomass of individual annual grasses.

Cattle and sheep are more negatively affected by drought because herbaceous plants are more sensitive to periodic moisture stress than woody plants. On the other hand, goats can better withstand drought periods with a relatively fewer browse species in their diet because browse plants are more nutritious and succulent and therefore less sensitive to drought. In addition, their ability to forage selectively on younger and high nutritious plant parts allows them a competitive edge in surviving periods of below average forage supply. This means that goats can withstand harsh conditions better than cattle or sheep.

Diet overlaps were generally low throughout the study period. These can, however, be expected to increase during periods of forage scarcity when opportunities of forage selection are restricted by limited species diversity and availability. Overlaps tended to be low during the growing seasons and high during plant dormancy seasons due to the reduced plant diversity and availability. Competition for forage between cattle, sheep and goats occurs more often during the dormant seasons and is more pronounced during years of subnormal rainfall where forage supply is low. Overlaps of diets during the growing seasons are less likely to result in serious competition for forage between animals, than overlaps occurring during dormant seasons, because forage biomass is abundant during the growing seasons.

Conclusion

Season was the main factor affecting herbage biomass availability and quality. Forage quality decreased from wet to dry season with greater declines in grasses than browse. Browse therefore, constituted a necessary and adequate supplement to herbage during the dry seasons, as dry season grasses are extremely deficient in most nutrients needed to meet livestock maintenance. Although it appears little can be done on seasonal decline in nutritional quality of forage, however some commonly used approaches in livestock management systems are as follows: a) Supplement the deficient nutrients by feeding enhanced supplements, b) Rangeland fertilization and especially brush management (e.g. prescribed burning to stimulation regrowth) may also be practical and profitable considering the economic value of livestock and c) Encouragement of those plant species in the rangeland that have above level of protein, by using certain grazing systems or range manipulation should be encouraged. Consistent monitoring of forage availability should be done in conjunction with monitoring of animal numbers and their respective needs for forage so that where necessary destocking can be based on sound scientific grounds to maintain the carrying capacity. Wet season diet of cattle and sheep were primarily herbaceous. Less selective livestock such as cattle, suffer more from poor diet quality during dry season compared to selective feeders such as goats that predominantly browse throughout the year and include fewer species of grasses. The potential for forage competition was higher throughout the year between cattle and sheep than between goats and cattle or between goats and sheep. A reduction in cattle numbers should enhance forage availability for sheep, and vice versa, but reducing the number of sheep or cattle have little or no effect on the foraging behavior of goats.

Conflict of Interest

The authors have not declared any conflict of interest.

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