DIET SELECTION AND INTAKE BY SHEEP FED IN A CAFETERIA SYSTEM

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ABSTRACT

Diet selection is an important requirement for evaluating the effects of herbivores on their environments. Herbivores select feeds to provide nutrients required for body functions. Inadequate information on diet selection and intake hinders development of feeding and utilization strategies. The objective of this study was to determine diet selection, intake by sheep fed selected humid and semi-arid grasses at Machakos Agriculture Training Centre (ATC). Five sheep were individually housed in pens of size 3 x 3 m and fed in a cafeteria system with six grasses. Data on feed intake, feeding time and number of visits was recorded for 5 days. Selectivity Index (SI) for each grass was calculated from intake data. The grasses were analyzed for chemical composition according to AOAC (1990). Analysis of variance (ANOVA) was carried using SAS (2000) to determine the effect of grass species on diet selection. Number of visits, feeding time, and the SI were different ($P<0.05$). Selectivity Index(SI) and Dry matter intake (DMI) had positive correlation ($P<0.05$) and ($P<0.0001$) respectively with number of visits ($r=0.90$) and feeding time($r=0.999$). Crude fibre had negative correlation ($P<0.05$) with *invitro* dry matter digestibility (IVDMD) ($r=-0.95$), SI ($r=-0.67$), number of visits($r=-0.71$), DMI ($r=-0.69$) and feeding time($r=-0.67$). Crude protein had positive correlation($P<0.05$) with IVDMD($r=0.24$). The result of this study indicated that diet selection can influence intake and hence performance of sheep. Diet selection studies can be used in designing feeding programmes for ruminant livestock in the tropics.

Keywords: Diet selection, cafeteria system, selectivity index

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INTRODUCTION

The nutrition of livestock especially for domesticated ruminants in arid and semi-arid regions in the tropics is a challenge to most livestock farmers. It is mainly based on the exploitation of range resources which are subject to high quantitative and qualitative variations over the year (Dicko and Sikena, 2004). Kahi *et al.* (2006) indicated that these areas have low rainfall, high temperatures, feed of poor quality and high incidences of livestock diseases leading to inefficiencies in nutritional management.

In open range grazing system, animals have a wide choice of feed resources which range from different parts of a plant to a single plant species and even to a genus of plants. This explains why animals degrade some areas in a range more than others which may also be in good condition.

Herbivores are able to select from a range of feeds to provide nutrients required to sustain their essential body functions (Forbes, 2007) and they are able to choose feeds which meet their nutritional needs and make them sense when they are satisfied. However, grazing systems in the tropics are relatively poor in plant diversity and may not present an opportunity for proper diet selection by ruminants. Jansen *et al*. (2007) explained that mammalian herbivores balance diet selection by maximizing nutrient intake and minimizing of plant secondary compounds, or by satiety. Diet selectivity can be considered in terms of selection of a particular feedstuff or part of feedstuff in mixed diets of one or more concentrate and feedstuff offered separately (Goetesh *et al.,* 2010). Herbivores earn energy for their maintenance and production from feeds (Wilmshurst *et al.,* 2000).

Diet selection is a source of variation when measuring intake, the essential problem being that more palatable parts are eaten first and this can cause the orts to have a different composition from the feed eaten. The amount and quality of feed available are the main factors influencing diet selection in herbivores. This is confirmed by the reality that the diet composition of any herbivore varies in both temporal (season) and spatial (location) aspects in response to changes in quantity and quality of available food (Dziba *et al*., 2003). Milne (1991) reported that the quantity and quality of forage consumed does not only determine the production of an animal species but also provide reliable information on the value of those plants in addressing the nutritional needs of the individual. Differences in diet selection and dry matter intake (DMI) among grass species exist and may be associated with differences in palatability which may be as a result of high levels of secondary plant metabolites such as condensed tannins (CT) as reported by Alonso Diaz *et al.* (2008). Although high fibre may reduce foraging efficiency and prolong the ingesta retention time in the rumen due to their low breakdown rate by rumen microbes, sufficient dietary fibre is however very important in ruminants for proper rumen functioning. Osuga *et al.* (2008) indicated that availability, palatability and nutritive value are the key determinants of the importance of feed for livestock feeding.

The choice of diet will affect both the nutritional status and the productive performance of the animal Thus the extent of preference and acceptability of feed is a key factor to consider when determining the best feed for livestock. To understand diet selection and intake estimation in grazing ruminants is a challenge due of the extensive situations of pastures and the choices offered. Cafeteria feeding system can give an understanding of diet selection and intake estimation in ruminants since confined animals are fed on a precise diet.

Despite considerable literature on dry matter intake, there has been less emphasis on the role of diet selection in the nutrition of the sheep (Kathy *et al*., 2009). There is also inadequate comparative information on diet selection and intake by sheep for humid and semi-arid grass species. Understanding the fundamental processes of diet selection and intake behavior of sheep is therefore a prerequisite for designing of efficient feeding management system to inform adjustments of feeding management strategies in order to cover the nutritional needs of the individual animal. This will lead to improved feeding efficiency, improved sheep performance and hence increased food and nutrition security and farmers' economy. The study was therefore carried out to determine diet selectivity of selected semi-arid and humid grasses and their effect on performance of sheep. The objective was to determine diet selectivity, feed intake and live weight gain in sheep fed selected semi-arid and humid grasses in a cafeteria system.

MATERIALS AND METHODS

Experimental site

The study was conducted at the Agriculture Training Centre (ATC) farm in Machakos County, Kenya. The farm is located three kilometers from Machakos town next to the Machakos people's park at latitude at latitude S1^{o} 32' 43.8108" and longitude E37^{o}14' 26.124" on an altitude of 1600 meters above the sea level. The site was selected because of its accessibility, availability of permanent sheep housing facility, constant supply of tapped water and electricity as well as adequate security. Both the diet selectivity experiment, feed intake and live weight gain study were done on the same site.

Diet selection study

Diet selection study was conducted in a cafeteria feeding system as described by Larbi *et al.* (1993). The choice of different grasses was used to represent different grazing conditions.

Experimental feed

Six (6) grass species namely *Brachiaria decumbens*, *Chloris gayana*, *Cenchrus ciliaris, Chloris roxburghiana*, *Enteropogon machrostachyus* and *Eragrostis superba* were used in the experiment. *Brachiaria decumbens* cv. Basilisk and Chloris *gayana* are humid while *Cenchrus ciliaris, Chloris roxburghiana, Enteropogon machrostachyus* and *Eragrostis superba* are semi-arid grasses. All grasses were sourced from Kibwezi East sub county, Makueni County and from farmers who were organized in community-based organization (CBO) for pasture production. The farmers were well trained on pasture establishment and management by Kenya Agricultural and Livestock Research Organization (KALRO) Kiboko. The grasses were regrowth of the November, December 2019 rains and were harvested in March 2020 using sickles. It was dried under shade for three days after which it was baled using manual hay box and transported to experimental site where it was stored in a well-ventilated store up to July 2020 when the experiment started.

Experimental animals

Five (5) healthy uncastrated growing male Dorper sheep aged between 12 and 18 months and of body weight between 26 kg and 29 kg were used in the diet selection experiment. The age of the sheep was determined through dentition. All the sheep were sourced from a ranch in Machakos County and transported by road in an open pickup to the experiment site. The 5 sheep were selected from a flock of 70 sheep, weighed and inspected by a veterinary surgeon for any abnormality before delivery to the experimental site. The sheep were treated for internal and external parasite with Ivermectin.

Housing, feeding and watering facilities

Each sheep was housed individually in a pen of measuring 3 x 3m. The pens were well ventilated and lit with natural light. The floor was cemented and insulated with wood shavings. Wood shaving was chosen to cover the floor because sheep do not eat it and it is absorbs moisture. The pens were cleaned twice every week and wood shavings replaced after cleaning. The pens were disinfected prior to introduction of the sheep and a foot bath was placed at the entry of the main entrance for the entire period of the experiment. Each pen was fitted with six movable feed troughs for each feed. The troughs were improvised by cutting plastic water Jerry cans above the centre. The feed troughs were movable ease of emptying of the feed remains into the weighing bucket. A watering trough was provided in each pen. All the troughs were of the same colour for uniformity and to avoid any colour bias on feed selection.

Plate I: Set up of feeding, watering and CCTV system

Plate II: Observation of diet selection in sheep

Feeding

The study lasted for 33 days with 28 days adjustment and 5 days for data collection. Hay from six experimental grass species was chopped separately into small uniform pieces using a grass chopper and each placed in a separate trough. Each sheep was offered experimental feed at 3% of body weight for each of the chopped grass species. The troughs were randomized every day to avoid "habit reflex" by the sheep. Each sheep was exposed to the experimental feeds daily between 0830 and 1830 hours in two regimes. First regime between 0830 to 1330 hours and the second regime between 1430 to 1830 hours. Each sheep was allowed to choose grass from any of six different feed troughs. Clean drinking water and mineral supplements were offered *ad libitum* throughout the experiment.

Data collection

Diet selection was based on data on time taken eating particular feed, number of times a particular feed was visited and the amount of feed eaten.

Chemical analysis of grass species

A small amount of herbage was taken from each bale used for feeding and carefully mixed before a composite sample of about 1.5 kg per treatment was drawn as described by (Njarui *et al.*, 2016) and constituted for analysis. The samples were ground to pass through 1.0 mm screen. The samples were then analyzed in triplicates for chemical composition at the Animal and Nutrition Laboratory at the University of Nairobi, College of Agriculture and Veterinary Services in Kabete.

Chemical components such as crude protein (CP), total ash, ether extract (EE), crude fiber (CF) and nitrogen free extract were determined by standard methods (AOAC, 1990). Fibre which includes Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) was determined according to Goering and Van Soest (1970). Cellulose was calculated as the difference between ADF and ADL, while hemicellulose was derived from the difference between NDF and ADF. The extent of *invitro* dry matter digestion (IVDMD) was determined using the Tilley and Terry (1963) two-stage method (48-hour rumen fluid, 48-hour pepsin digests).

Selectivity index

To measure the degree of dietary selectivity shown by the sheep, the tendency to select the principal plant was quantified by calculating the Ivlev selectivity index (Gallardo *et al.,* 2014).

$S_i=(r_i-p_i)/(r_i+p_i)$

Where;

S_i is the selectivity index of i^{th} grass.

r^i is the proportion of i^{th} grass in the diet consumed

p^i is the proportion of i^{th} grass in the total diet offered or available.

The values of r and p range from 0 to 1 (Hejcmanová *et al*., 2019) with the S_i values ranges from -1 to +1. An Si value of -1 indicates rejection meaning the relative consumption of the i^{th} grass is lower than its relative availability while a value of +1 indicates preference meaning the relative consumption of the i^{th} grass is higher than its relative availability. The S_i=0 means a grass consumption was in proportion to its abundance or availability (Gallardo *et al.,* 2014).

Data analysis

Data on time taken, dry matter intake, number of trough visits and selectivity index was $\log_{10}$ transformed before analysis. Transformed data was subjected to Analysis of variance (ANOVA) in a complete randomized design (CRD) with the 6 grasses as the treatments and the five sheep as the replications. The time spent on each feed (trough), dry matter intake, number of times a particular grass was visited and the selectivity indices (SI) for different grasses were summarized across the five (5) sheep and the average computed. T-test was used to test the effect of grass category (humid and semi-arid) on diet selectivity The effect of grass species on diet selectivity and intake by sheep was determined by analysis of variance using (SAS, V 2000) based on the model below:

$$Yij = \mu + Ti + Eij$$

Where: Y_{ij} is the ith observation of the ith treatment (dependent variable)

μ is overall mean (constant/intercept), T_i is effect of the $_i$th grass treatment (1-n)

E_i is the error associated with $_i$th treatment (residual error)

Correlation analysis was done to establish the relationships between selectivity index (SI), chemical variables of the feed and the grass category (whether humid or semi-arid grass). Where the means were significantly different, Least Significant Difference (LSD) method was used to separate means at 5% probability level (Steel and Torrie, 1980).

Correlation analysis was done to determine the relationships between dry matter intake, number of visits, time spent feeding on the grasses, SI, chemical variables and invitro dry matter digestibility of the grasses

RESULTS

Diet selectivity and dry matter intake

Differences (P<0.05) were recorded for dry matter intake, feeding time, number of visits, and selectivity index among the different grasses (Table I). There was higher Dry matter intake and time spent feeding were higher (P<0.05) in the sheep fed on *E. macrostachyus* than the in all the other grasses.

TABLE I- MEAN NUMBER OF GRASS VISITS, DRY MATTER INTAKE, FEEDING TIME, AND SELECTIVITY INDEX (SI) FOR DORPER SHEEP FED DIFFERENT GRASSES

Grass	Dry Matter Intake(g/day)	Time spent feeding (seconds)	Number of Visits	SI
Enteropogon macrostachyus	635[a]	2924.2[a]	3.7[a]	0.6[a]
Cenchrus ciliaris	84.2[b]	255.7[b]	2.0[ab]	-0.3[ab]
Eragrostis superba	28.8[c]	249.4[b]	1.4 [bc]	-0.5[bc]
Chloris gayana	28.8[c]	61.5[bc]	0.70 [cd]	-0.7[cd]
Chloris roxburghiana	16.4[cd]	11.1[cd]	0.3[de]	-0.8[de]
Brachiaria decumbens	10.8[d]	8.2[d]	0.2[e]	-0.9[e]
Mean	134	584.99	1.37	-0.41
SEM	42.131	199.55	0.242	0.1

Means with different superscripts in the same column are different ($P<0.05$).

SEM = Standard Error of Mean

Effect of grass category, on dry matter intake, diet selection behavior of sheep

Results of the current study showed difference ($P<0.05$) in that dry matter intake, time taken feeding, number of visits and selectivity index between semi-arid and humid grasses species. (Table II). Dry matter intake, feeding time, number of visits and selectivity index were higher($P<0.05$) in semi-arid grasses.

Chemical composition and *invitro* dry matter digestibility of grasses

The results of ANOVA showed differences ($P<0.05$) in chemical composition (DM, Ash, CP, NDF, ADF, ADL, Ca, P) and *invitro* dry matter digestibility(IVDMD) among the six experimental grasses (Table III).

TABLE II- MEAN NUMBER OF GRASS VISITS, DRY MATTER INTAKE, FEEDING TIME, AND SELECTIVITY INDEX (SI) FOR SHEEP FED HUMID AND SEMI-ARID GRASS CATEGORIES

Grass Category	Dry matter Intake	Feeding Time	No. of visits	SI
Semi-arid	191.1[a]	860.1[a]	1.82[a]	-0.232[a]
Humid	19.8[b]	34.8[b]	0.47[b]	-0.773[b]
Mean	134	585	1.37	-0.41
SEM(P<0.05)	42.13	199.6	0.241	1.00
t value	-2.55	-2.49	-4.03	-3.87
DF	28	28	23.7	23.6

Means bearing different superscripts in the same column are different ($P<0.05$)

TABLE III- CHEMICAL COMPOSITION AND *IN VITRO* DIGESTIBILITY OF GRASSES USED IN THE EXPERIMENT IN (g/kg DM) FOR THE SIX GRASSES USED IN THE EXPERIMENT

Grass	**ASH**	**CP**	**NDF**	**ADF**	**ADL**	**IVDMD**	**Ca**	**P**
Eragrostis superba	78.5^{c}	53.5^{b}	728.4^{ab}	494.3^{a}	139.7^{b}	321.9^{d}	2.6^{a}	1.2^{bc}
Chloris gayana	73.6^{c}	48.2^{c}	757.4^{a}	483.1^{bc}	163.2^{a}	310.3^{d}	2.0^{b}	1.4^{ab}
Cenchrus ciliaris	119.4^{a}	56.3^{a}	699.5^{b}	525.6^{a}	114.6^{c}	415.9^{b}	2.4^{ab}	1.7^{a}
Brachiaria decumbens	101.3^{b}	36.2^{d}	743.4^{a}	479.0^{c}	155.5^{a}	385.7^{c}	2.0^{b}	1.0^{c}
Eragrostis macrostachyus	107.7^{b}	57.2^{a}	746.7^{a}	474.0^{c}	102.6^{d}	443.4^{a}	2.0^{b}	1.2^{bc}
Chloris roxburghiana	102.7^{b}	47.9^{c}	750.4^{a}	439.4^{d}	112.6^{cd}	407.6^{b}	1.8^{b}	1.2^{bc}
Mean	97.23	49.88	737.6	482.5	131.4	380.8	2.13	1.28
LSD	7.021	1.897	33.193	12.625	12.115	15.747	0.54	0.434
SEM(P<0.05)	3.984	1.729	5.945	6.371	5.697	11.991	0.09	0.075
P-value	<0.0001	<0.0001	0.026	<0.0001	<0.0001	<0.0001	0.05	0.04

CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, IVDMD = *invitro* dry matter digestibility, Ca = calcium, P = phosphorus
Means bearing different letters in the same row are significantly different($P<0.05$), SEM=Standard error of means

Proximate composition, *invitro* dry matter digestibility and diet selection

Correlation analysis showed that DMI had a strong and positive correlation with feeding time, number of feed visits and selectivity index. Crude fibre and DMI, IVDMD, feeding time, number of feed visits and selectivity index were negatively correlated. (Table IV).

TABLE IV- CORRELATION BETWEEN PROXIMATE COMPOSITION, *INVITRO* DRY MATTER DIGESTIBILITY (IVDMD), DRY MATTER INTAKE (DMI), FEEDING TIME (FT), NUMBER OF FEED VISIT (NV) AND SELECTIVITY INDEX (SI)

	CP	CF	IVDMD	DMI	FT	NV	SI
CP	1	-0.28	0.23	0.53	0.53	0.79	0.74
CF		1	**-0.94	-0.65	-0.63	-0.63	-0.64
IVDMD			1	0.60	0.56	0.50444	0.54307
DMI				1	***0.997	*0.90	**0.95
FT					1		**0.95186
NV						1	***0.99
SI							1

*Significance level: (P≤0.05), ** significance level (P≤0.01), ***significance level (P≤0.001)..

DISCUSSION

Diet selection

Results of this study showed that *E. macrostachyus* had the highest selectivity index. The selectivity index for the grasses was in the order; *E. macrostachyus > C. ciliaris > E. superba > C. gayana > C. roxburghiana > B. decumbens*. The higher selectivity index in *E. macrostachyus* may be attributed to higher palatability of the grass, higher nutritive value and digestibility compared to the other grasses. Provenza *et al* (2003) reported that differences in plants secondary metabolite compounds, macronutrient concentrations, and flavors could lead differences in preference by sheep for the different grasses. Ziblim *et al.,* (2019) reported that differences in the nutritional, anti-nutritional and other astringent tastes in the forage might have been partly accountable for the differences in the observed selectivity index.

Diet selectivity does not only depend on plant species, but also on the nutrient composition and digestibility.

Other factors like tastes, smell and texture of the forage might have been partly accountable for the differences in the observed selectivity indices. Forage quality is commonly interpreted in terms crude protein, fibre components and digestibility thus selectivity index is associated with the quality of the grass. These are discussed below in relation to selectivity index.

Dry matter intake

The high dry mater intake of *E. macrostachyus* by sheep can attributed to the high selectivity due to higher nutritive value of the grass. The values of DMI were higher for semi-arid category (191.1) than the humid category (19.8), a phenomenon that can be attributed to differences in nutritive value of grasses categories average. There was a very strong positive correlation (r=0.997,) between dry matter intake(DMI) and feeding time. The DMI of *E. macrostachyus* was highest and so was the time spent by sheep eating the grass. The least DMI was recorded in *B. decumbens* and so was the time spent feeding on it. It was also found that as feeding time and number of visits increased, there was a concurrent increase in dry matter intake. This is important as it is one of the criteria used for assessing preference and acceptability (Kalio *et al*., 2006).

Crude Protein

Afzal and Ullah (2007) reported that crude protein (CP) and digestible dry matter are the most important components of a feed. In this study, all the grasses had lower CP than the minimum CP of 75 g/kg of DM necessary for optimum rumen function and production as suggested by Van Soest (1994). The low CP was attributed to poor management of the grass at harvesting and baling which may have led to loss of leaves. Further the *B. decumbens* which is a humid grass was grown in lower eastern parts of Kenya and generally due to the high temperatures experienced in the region, the growth was fast and accumulated more fibre resulting to low CP and thus low digestibility (Njarui *et al*, 2016). The results of this study agree with De Klein *et al* (2006) who recorded that CP content determines forage digestibility and rate of ingest passage in ruminants, which impacts on the dietary nourishment. The study also showed that C. *gayana,* which is also a humid grass, was superior in quality than *B. decumbens* though both were grown in semi-arid conditions. On the contrary *C. ciliaris, E. macrostachyus*, *E. superba* and *C. roxburghiana* are range grasses adapted to high temperatures and moisture stress experienced in semi-arid region and therefore their CP levels were higher than for humid grasses.

Ash and minerals

Calcium (Ca) and phosphorous (P) are important minerals in the diet of animals because they are involved in the development of bones (Miles and Manson, 2000). According to NRC (2007), Ca requirements for small ruminants range from 1.4-7.0 g/kg^{-1} DM while P requirement ranges from 0.9-3.0 g/kg^{-1} DM. All the grasses in this study attained this minimum requirement for Ca and P. The ash content in all the grasses was within the range of 30-120 g/kg DM reported by Linn and Martin (1999).

Fibre and lignin

Fiber fractions are components of cell wall that are relatively less digestible than starch (Tavirimirwa *et al.,* 2012). The amounts of fibre components determine forage quality and intake levels. Van Suun (2006) considered forages of NDF > 500 g/kg DM as poor-quality forage noting that grasses with NDF < 500 g/kg of DM as high quality while the ones with NDF > 600 g/kg DM as poor. In this study, all the grasses had NDF > 600 g/kg of DM thus poor quality according to Van Suun (2006) and this may explain the low intake and digestibility of the grasses.

Acid detergent fibre in a forage consists of cellulose and lignin and it relates to digestibility. Like NDF, high values ADF in a forage depresses digestibility. Nussio *et al.* (1998), noted that forage with ADF content of 400 g/kg of DM or more exhibit low intake and digestibility. In the current study, all the experimental grasses had ADF more than 400 g/kg of DM which also explains the low intake and digestibility of the grasses. Similarly, Mean ADL values for all the grasses ranged between 102 - 163 g/kg DM which is far above 34 - 57 g/kg DM, the range reported by Sultan *et al.* (2007) for range grasses when mature. The study also showed a negative correlation (r=-064) between CF and selectivity index though the relationship was not significant (P<0.05)

***Invitro* dry matter digestibility**

De Gues (1977) reported that the digestibility of tropical grasses ranges between 500 - 650 g/kg DM while that of temperate grasses is higher and ranges between 650 and 800 g/kg DM. Digestibility of all grasses in this study ranged from 310 to 443 g/kg DM which is below the range indicated by De Gues (1977). The low digestibility in all grasses can be attributed to the high fibre and lignin levels. The current study showed a strong negative correlation between crude fibre and IVDMD (r=0.93, P<0.01). This study also found a weak positive correlation between IVDMD and (r=0.23, P>0.05). However, digestibility was higher(P<0.05) in *E. macrostachyus* grasses which comparatively had higher levels of CP while *C. gayana* had the digestibility(P<0.05) although its CP was not the lowest and this may be attributed to other feed factors like presence of secondary plants metabolites. Mean digestibility for semi-arid category was higher(P<0.05) than humid categories the study also showed a positive correlation (r=0.563) thus selectivity index would increase with increase in IVDMD. Grasses in the current study were stored for three months before the feeding study was done and this may have contributed to increased structural carbohydrates leading to low digestibility (Jackson *et al.* 2007).

CONCLUSION AND RECOMMENDATION

Enteropogon macrostachyus was the most preferred grass and it had the highest CP DMI values thus, intake and contributed to the highest weight gain in sheep. The study also showed that diet selection does not only depend on plant species, but also on the macro elements present. Other factors like taste, smell and texture of the forage might have been partly accountable for the differences in the observed selectivity indices.

Further research should be conducted where the grasses are established in different ecological zones to establish the best mix of grasses.

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