DIET SELECTION, INTAKE AND WEIGHT GAIN OF DORPER SHEEP FED ON SELECTED GRASSES IN A CAFETERIA SYSTEM IN MACHAKOS COUNTY, KENYA.

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DECLARATION

I understand that plagiarism is an offense and I, therefore, declare that this thesis is my original work and has not been presented to any other institutions for an award.

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ABBREVIATIONS AND ACRONYMS

ADF	**:**	Acid Detergent Fibre
ADG	**:**	Average Daily Gain
ADL	**:**	Acid Detergent Lignin
ANOVA	**:**	Analysis of Variance
AP	**:**	Animal Preference
AOAC	**:**	Association of Official Analytical Chemists
ATC	**:**	Agriculture Training Centre
CBO	**:**	Community Based Organization
CCTV	**:**	Closed Circuit Television
CF	**:**	Crude Fibre
COP	**:**	Coefficient of Preference
CP	**:**	Crude Proteins
CRD	**:**	Completely Randomized Design
CT	**:**	Condensed Tannins
DM	**:**	Dry Matter
DMI	**:**	Dry Matter Intake
DF	**:**	Degrees of Freedom
EE	**:**	Ether Extracts
EPA	**:**	External Plant Attributes
FCE	**:**	Feed Conversion Efficiency
FCR	**:**	Feed Conversion Ratio
GLM	**:**	General Linear Model
KALRO	**:**	Kenya Agriculture and Livestock Research Organization
LWG	**:**	Live Weight Gain
LSD	**:**	Least Significant Difference
MAM	**:**	March April May
NDF	**:**	Neutral Detergent Fibre
NFE	**:**	Nitrogen Free Extracts
NRC	**:**	National Research Council
IVDMD	**:**	*In-vitro* Dry Matter Digestibility

OFT	**:**	Optimal Foraging Theory
OMD	**:**	Organic Matter Digestibility
OND	**:**	October November December
SAS	**:**	Statistical Analysis System
SE	**:**	Standard Error
SI	**:**	Selectivity Index
TP	**:**	Total Phenols
TT	**:**	Total Tannins

DEFINITION OF TERMS

Cafeteria feeding: The form of feeding where animals are offered different feeds separately at the same time so that there is free choice of feed by the animal.

Diet: A mixture of feed stuff used to supply nutrients to an animal (NRCS, 2012).

Diet selection: Preference of a particular feedstuff or part of feedstuff in mixed diets or selection of one or more feeds offered separately (Goetesh *et al*., 2010).

Preference: The selection of a plant species from among many different species and is mainly based on the abundance of the plant species, its external plant attributes, and the animal species (Osolo *et al.,* 1996).

Preferred forage: Forage consumed in a higher ratio in relation to its abundance in the feeding area, irrespective of the extent to which it contributes to the entire diet (Dziba *et al.* (2003a).

Principal forage: Forage considered to have a great contribution to the diet selected by an animal, irrespective of its preference in relation to other plant species offered (Dziba *et al.,* 2003a).

Selectivity index: The proportion of one forage in an herbivore's diet in relation to its proportion in the environment (Zhang *et al*., 2022).

Compensatory growth: An accelerated growth of an organism following a period of slowed development, particularly as a result of nutrient deprivation(Lawrence & Fowler, 2002).

ABSTRACT

Livestock is a key asset and a primary livelihood resource for rural households in most parts of the world and accounts for nearly 95 per cent of family income in the Arid and Semi-Arid Lands (ASALs) in Kenya. Despite high economic importance of livestock, inadequate nutrition results to low livestock productivity in Kenya. Ruminant feeding in the ASALs is mainly based on the exploitation of range feed resources. Grazing ruminants forage on different plant species with varying levels of nutrient and toxins. Despite these complex grazing situations, sheep can select a suitable diet and regulate intake of toxic substances. There is therefore a need understand diet selection and its role in the nutrition of sheep. A study to assess diet selection, intake and live weight gain of sheep fed on different grasses was conducted at Machakos Agriculture Training Centre (ATC) in two experiments. Five sheep housed in individual pens of size (3 x 3m) were fed in a *cafeteria system* with six grasses namely *Brachiaria decumbens* cv. Basilisk, *Chloris gayana*, *Cenchrus ciliaris, Chloris roxburghiana, Enteropogon macrostachyus* and *Eragrostis superba* were used during experiment 1. Data on dry matter intake (DMI), feeding time and number of visits were recorded for 5 consecutive days. Selectivity index (SI) for each grass was calculated from intake data. The grasses were analyzed for chemical composition according to Association of Official Analytical Chemist (AOAC) (1990). Analysis of variance (ANOVA) was conducted using the SAS, 2000 model to determine the effect of grass species on diet selection. Four grasses and sixteen Dorper sheep aged between 12 and 18 months and weighing between 18 and 29 Kgs were used in experiment 2. The sheep were grouped into four groups balanced for age and weight. Each group was randomly allocated one dietary treatment. Mineral licks and water were provided *ad libitum* throughout the study. Data on intake and weight gain were computed for 42 days and analyzed by General Linear Model (GLM) procedure of SAS 2000. Results of experiment 1 showed that number of visits, feeding time, and the selectivity index (SI) were higher ($p<0.05$) in sheep fed on semi-arid grasses than in the sheep fed on humid grasses. Results of experiment 2 showed that dry matter intake (DMI) and average daily gain (ADG) were higher ($p<0.05$) in sheep fed on semi-arid grasses than in the sheep fed on humid grasses. Crude fibre had a negative correlation with ADG ($r=-0.258$), SI (-0.675), DMI ($r=-0.627$) and *in vitro* dry matter digestibility (IVDMD) ($r=-0.997$). Crude protein had a positive correlation with ADG (r=991), selectivity index ($r=0.792$), dry matter intake ($r=0.955$), and *in vitro* dry matter digestibility($r=0.446$). The result of this study indicated that diet selection is influenced by nutritive value and digestibility of the forage. These findings also show that diet selection can influence intake and hence weight gain of sheep. Diet selection studies can be used in designing feeding programmes for ruminant livestock in the tropics.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Livestock is considered one of the key assets for rural households in most parts of the world and it is a primary livelihood resource for most rural communities. According to FAO (2012), about 752 million of the world's poor keep livestock mainly for income generation, produce food for subsistence use, manage risks and build up assets for security purposes. Moreover, they provide manure and draft power for crop production and are commodities for social functions and symbols of social status (Njarui *et al*., 2021). The sector supports livelihoods and plays an important role in reducing poverty for most rural households in Kenya and Africa at large (Engida *et al*, 2015).

Livestock production contributes to almost 90 per cent of the livelihood of households and accounts for nearly 95 per cent of family income in the Arid and Semi-Arid Lands (ASALs) in Kenya (Kenya Ministry of Agriculture, 2008). The ASALs cover 80% of Kenya's landmass (Mganga *et al*., 2010) and support 60% of the livestock population and the largest proportion of wildlife as well as hosting 25% of the human population (Farah *et al*., 2003). These areas are characterized by low rainfall, high temperatures, poor quality feed resources, and high incidences of livestock diseases (Kahi *et al.,* 2006).

In Africa, pastoralism accounts for over 70% of the total livestock production which supports the livelihoods of over 200 million people (WISP, 2010), while in Kenya, it's the main source of livelihood to millions of people living in these lands (Amwata *et al.* 2015) According to Devendra, 2002, African pastoral farming systems own sheep and goats more than any other species of domestic livestock except poultry. This is because sheep and goats have lower feed requirements, fast reproduction and the ease with which they can be handled, thus making them important for resource-poor households and often the asset of vulnerable groups, such as women and children (Devendra, 2002). Like goats, sheep are found in many parts of Kenya and are an important source of income to many small-holder farmers and are preferred to cattle as they can be converted to cash easily (Ahuya and Okeyo, 2006). Silva *et al.,* (2022) recorded that although there are enormous challenges to address in production, nutrition and reproduction in extensive production systems, sheep and goats are very important in the context of global food security and the use of rangelands that may have minimal alternative agricultural use. In addition, the growing demand for livestock products in developing countries due to increasing population and urbanization (Thornton, 2010) makes sheep and goats important contributors to food security compared to large ruminants. This is due to their higher offtake, their shorter generation interval and higher prolificacy.

Despite high economic and social importance, livestock productivity in Africa is low, mainly due to short supply and low nutritive quality of available feed resources which is severe during the dry seasons leading to a sharp decline in livestock productivity (Njarui *et al.,* 2021). According to Njarui *et al.* (2011), feed is the major input factor in livestock production systems and accounts for between 60 - 70% of the production cost and its availability and quality are strongly linked to livestock productivity. Inadequate and poor quality feeds are major feed factors that contribute to low productivity of ruminants (Njarui *et al.,* 2016). He further recorded that there is a deficit in feed resources for about 4 - 6 months in a year across many regions in Kenya particularly during the dry season when there is limited pasture growth. According to Ndathi *et al. (2011*), acute shortage of forage to sustain livestock populations through the dry seasons has threatened the livelihood security of pastoral communities. He further pointed that death of livestock at the peak of the prolonged droughts has been a common phenomenon in the horn of Africa in the last few decades. For example, according to the UNDP report (2010), livestock worth more than KSh70 billion was lost in North Eastern Kenya in the 2005/2006 drought. Muchina and Warden (2009) reported that the modern-day dry seasons have been characterized by extended periods of drought conditions that result in high mortality rates of livestock.

The full potential of the ASALs for livestock production can be achieved by developing livestock feed management strategies which aim at boosting the quantity and quality of pasture in order to supply livestock with the required nutrients. In Africa, natural vegetation makes up a major part of the diet of ruminants. To enhance livestock production in these ASALs, it is imperative to improve pastures, comprising of grass and browse species. The improvement of such pastures is impossible to achieve without adequate understanding of herbivores' feeding behaviour and their interaction with browse and pasture (Abdel Rahim, 2012; Basha *et al.*, 2009). A key to improving the management of rangelands is the development of a sound understanding of diet selection. Diet selection describes the decisions animals make with regard to the plant material (plant parts, plant species and patches) they choose (Newman *et al*., 1995)

Ruminant feeding in the ASALs is mainly based on the exploitation of range feed resources which exhibit great variations over the year in terms of both quantity and quality (Dicko and Sikena, 2004). Pasture is a major component in the diet of these ruminants and is the main source of nutrients during the dry season. Devendra (1986) reported that feed is the most limiting factor to the nutrition of sheep in most parts of the tropics due to its effect on their performance. In most parts of the tropics, small ruminants and generally all animals fail to prove their full genetic potential for higher production due to inadequate nutrition (Tomar *et al*., 2022)

Devendra (1980) reiterated that low productivity of sheep in the tropics is consistent with inefficiencies in nutritional management. Efficient utilization of feeds is thus an important means of achieving the production potential of sheep and goats. Pasture and fodder are often regarded as important basal feed resources for grazing ruminants. It is thus important to understand how these herbivores select feed resources to cover their nutritional requirements. Basha *et al.* (2012) reported that diet selection patterns in herbivores are controlled by variations in features among and within plant species. Dziba *et al.* (2003a), reported that diet selection patterns are irregular in both space and time as a result of seasonal variations in forage availability or differences in forage chemical and physical properties. Alonso *et al.* (2008) found out that differences in diet selection and dry matter intake (DMI) exist among grass species and may be associated with differences in palatability which may be attributed to different levels of nutrients and secondary plant metabolites such as condensed tannins (CT). Abdou *et al*. (2011) suggested that proteins are the limiting factor to animal performance while Ganqa *et al*. (2005) described crude protein as the main factor affecting diet selection in herbivores. Although Baumont *et al*.

(2000) noted that foraging efficiency is low in forages with high-fibre content leading to prolonged retention time of ingesta and low rate of breakdown by rumen microbes, adequate amounts of dietary fiber however very important in ruminants for proper rumen functioning hence prevention of rumen disorders (Zebeli *et al*., 2012).

Despite considerable literature on dry matter intake, little emphasis is put on the role of diet selection in the nutrition of sheep (Soder *et al.,* 2009). Further, the author noted that diet selection and preference research models involve a choice between two forage species. In a grazing situation, ruminants are confronted with both spatial and temporal complications of food sources that contain many different plant species at different times. Ngwa *et al.* (2003) noted that ruminants face a complex array of plant materials with varying levels of nutrient types and toxic substances. Despite these complex grazing situations, ruminants make different diet combinations to maximize their biological performance. Mtenga *et al*. (1992) and Kalio *et al*. (2012) found that preference and acceptability of feed influence utilization of any feed resource and may be attributed to the animal's behavioural feeding patterns. Osuga *et al.* (2008) indicated that availability, palatability and nutritive value are important aspects of feed in livestock feeding. Goats and sheep select forage that meets their nutritional requirements from a wide range of forage types and they avoid those which can be toxic (Ngwa *et al.,* 2003). The choice of diet affects the nutritional status and performance of the animal thus preference and acceptability of feed is a key factor to consider when determining the best feed for livestock (Soder *et al.,*2009).

To achieving the production potential of sheep in the ASALs, strategies for efficient utilization of feed and nutrition management should be developed. Knowledge on diet selection, intake and live weight gain of sheep is therefore necessary in development of efficient feed utilization and nutrition management strategies.

1.2 Statement of the Problem

Sheep are a cheap source of proteins as they reproduce faster and require less feed compared to large ruminants. However, sheep productivity in most parts of the tropics is low due to inadequate nutrition (Devendra, 1986) resulting from low quantity and quality feed. In Africa, natural pasture and browse make up a major part of the diet of ruminant livestock. To enhance livestock production, it is imperative to improve the natural vegetation, mainly grass and browse species in rangelands. The improvement of such pastures is impossible to achieve without an adequate understanding of plant-herbivore interaction and feeding behaviour. Further, for efficient utilization of feed resources in the rangelands, knowledge of diet selection and feed intake by herbivores is important.

Soder *et al.* (2009) reported that most diet selection and preference models involve a choice between only two forage species. However, there is no information on the role of diet selection in the nutrition of sheep when offered multiple grass species (Soder *et al.,* 2009). Further, comparative information on diet selection and intake by sheep for humid and semi-arid grasses is lacking. This information gap is a challenge in the development of suitable nutrition management strategies for efficient feed utilization. The purpose of this study, therefore, was to bridge this knowledge gap by assessing diet selection, intake and live weight gain of sheep fed on selected humid and semi-arid grasses in a cafeteria feeding system.

1.3 Objectives of the Study

1.3.1 Broad Objective

The main objective of the study was to assess diet selection, feed intake and live weight gain of Dorper sheep fed on selected semi-arid and humid grasses in a cafeteria feeding system.

1.3.2 Specific Objectives.

The specific objectives of the study were:

i. To examine the difference in diet selection in sheep fed on humid and semi-arid grasses in a cafeteria system.
ii. To assess the difference in dry matter intake (DMI) in sheep fed on humid and semi-arid grasses in a cafeteria system.

iii. To investigate the relationship between grass chemical composition and diet selection in sheep.
iv. To determine the relationship between diet selection, intake and live weight gain in sheep.

1.4 Hypotheses

i. There is no difference in diet selection in sheep fed humid and semi-arid grasses in a cafeteria system.
ii. There is no difference in dry matter intake (DMI) in sheep fed humid and semi-arid grasses in a cafeteria system.
iii. There is no relationship between the grass chemical composition and diet selection in sheep.
iv. There is no relationship between diet selection, intake and live weight gain in sheep.

1.5 Justification

In a grazing situation, ruminants are confronted with both spatial and temporal complications of food sources that contain different plant species at different times and with varying levels of nutrient types and toxic substances (Ngwa *et al.*, 2003). Despite these complex grazing situations, ruminants make different diet combinations through selection which meet their needs for nutrients and regulate their intake of toxins in order to maximize their biological performance (Provenza *et al.*, 2002) Although the choice of feed the sheep forages affects its nutritional status and performance, little emphasis is put on the role of diet selection in the nutrition of sheep and most diet selection and preference research models involve a choice between two forage species (Soder *et al.*, 2009). As a result, understanding diet selection and intake in an open grazing situation where is a wide range of forage species which are maturing at different times is a challenge.

Cafeteria feeding technique has been classified as one of the critical means for access acceptability of feeds in ruminants and can give an understanding of diet selection and intake estimation in ruminants where multiple forage species are involved (Deng *et al* 2017). This study would provide additional information on the role of diet selection in the nutrition of sheep fed multiple forage species. In addition, the study will provide information which can be used to inform adjustments as well as designing appropriate sheep feeding strategies for efficient feed utilization. Efficient feed utilization would improve sheep productivity and thus lead to increased food and nutrition security as well as farmer's income. This study will provide useful information to farmers, animal production extension systems and researchers in animal nutrition and pasture science.

1.6 Limitation

Several limitations were encountered during the study. Firstly, there was unusual continuous rain in the month of February 2020 when the grass was expected to be harvested. This delayed the process of harvesting, drying and bailing of the grass hence the grass overgrew. Harvesting was done in the month of March 2020 but in small quantities to allow drying in shelters because it was the March, April, May (MAM) rain season Secondly, restriction of Movement due Covid -19 interfered with follow ups of bailing process hence delayed both bailing and transportation of the bailed hay to Machakos Agriculture Training Centre (ATC) in Machakos county for experiment. In addition, poor roads delayed ferrying the grass from the farms to accessible roads where lorries would collect and transport to experimental site. Donkey carts were used to ferry harvested grass from the farm to the drying shelters and to ferry the baled grass from the farm to accessible road. Further, the range grasses (*Cenchrus ciliaris*, *Enteropogon macrostachyus*, *Eragrostis superba and Chloris roxburghiana*) were not available in Machakos County and therefore it had to be sourced from Kibwezi east Sub County in Makueni County.

1.7 Scope

This study was carried out at Machakos Agriculture Training Centre (ATC) in Machakos County. It considered the Dorper sheep only lection, feed intake and live weight gain of Dorper sheep fed on selected humid (*Chloris gayana* and *Brachiaria decumbens*) and semi-arid grasses (*Cenchrus ciliaris, Enteropogon macrostachyus, Eragrostis superba and Chloris roxburghiana*) in a cafeteria system. The study lasted for 90 days (25th July, 2020 to 23rd October, 2020). Data analysis was guided by use of SAS (2000). The operations, activities and data collection were strictly confined within the boundaries set by the objectives of this study. The results of the study are applicable in the sector of livestock development and especially in the nutrition of sheep which will ultimately lead to improved sheep productivity.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Open Range Grazing Systems

In an 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 in rangelands degrade some areas more than others which may also be in good condition. Van Soest (1982) found out that if a fresh paddock containing a single plant species is grazed for several days, selection and intake will change as the forage supply decreases. Similarly, selection and intake also change as the forage matures. Dicko and Sikena (2004) reported that studies of feeding behaviour have been carried out through various ways such as visual observation of grazing activity, fecal output examination, use of diet samples collected from rumen and esophageal fistulae and comparative analysis of quantity of forage offered minus the quantity of forage not eaten. Both plants and animal factors affect feeding behaviour and modification of the latter can occur due to environmental factors such as human interventions (Van, 2006; Dicko *et al.*, 1983).

2.2 Cafeteria Feeding

Cafeteria feeding is a form of feeding where animals are offered different feeds separately at the same time. The extent to which an animal can ingest certain feeds in a choice situation can be assessed through cafeteria feeding. According to Manteca *et al.* (2008), the availability of alternative feeds offers the individual animal the possibility to choose what fits its nutritional requirements best in order to make the right diet mix and reduce stress resulting from inappropriate rations. In cafeteria feeding, animals can assess the feed to eat, avoid or select a combination that performs self-medication thus improving health. Distel & Villalba (2018) recorded that ruminants search for forage species that generate comfort and avoid those which generate discomfort. Meier *et al.* (2012) recorded that cafeteria feeding experiments help to improve understanding of the feeding behaviour of animals, and may allow adjustment of management strategies to cover the nutritional requirements of the individual animal. The cafeteria feeding experiments can also be applied to test the animal's capability to choose diet that cover their nutritional requirements (Meier *et al.*, 2012).

Van Soest (1982) reported that if no great quantity of any one plant is eaten, the relative amounts of poisons consumed across the spectrum of plant species will not result in dangerous intake. In grazing conditions, ruminants are faced with a complex array of plant materials differing in both the levels of nutrients as well as toxic substances from which they make diet combinations to meet the animals requirement thus maximize their biological performance(Ngwa *et al*., 2003). Cafeteria feeding allows animals to make the desired diet mix thus diluting the toxic substances and concentrating useful substances.

2.3 Diet Selection by Sheep

Goetesh *et al*. (2010) considered diet selection as the preference for a particular feedstuff or part of feedstuff in mixed diets or the selection of one or more feeds offered separately. Feeds provide energy for maintenance and production functions of the animal as well as microelements, proteins, vitamins, and amino acids. To sustain their essential body functions, herbivores select from a wide range of feeds to meet their nutrients requirement (Forbes, 2007). The feed resource range is even bigger for intermediate feeders, such as sheep that graze selectively but can consume both herbaceous and woody vegetation (Larson *et al.,* 2015). In the tropics, grazing systems are relatively poor in plant diversity and may not present an opportunity for proper diet selection by herbivores. The availability of feed also influences selectivity as pointed out by Van (2006) that increasing feed availability encourages selective feeding. Jansen *et al.* (2007) noted that balancing diet selection in herbivores can be achieved through maximizing nutrient intake and minimizing intake of anti-nutritive compounds, or by satiety. Diet selection gives herbivores the opportunity to choose and eat what meets their nutritional needs and reduce stress resulting from inappropriate rations (Manteca *et al*., 2008; Provenza, 1995).

Diet selection is a source of variation in the feed an animal eats because the more palatable parts are eaten first and the orts left have a different composition from the feed eaten. The main factors influencing diet selection in herbivores are the amounts and quality of feed available. Dziba *et al.* (2003a) confirmed that variations occur in diet composition of any herbivore with respect to spatial and temporal aspects. Milne (1991) reported that the amount and quality of forage provide information on the value and role of plants in animal nutrition in addition to contributing to the animal's production functions. According to Aregheore *et al.* (2006), natural forage has different species with different levels of acceptability and palatability, which is as a result of forage composition. Preference involves the selection of a plant species from among many different species and is mainly based on the abundance of the plant species, its external plant attributes, and the animal species (Osolo *et al.*, 1996). Diet selection on the other hand relies on preferred and principal forage. According to Dziba *et al.* (2003a), a preferred forage is consumed in a higher ratio relative to its abundance in the feeding area, irrespective of the extent to which it contributes to the entire diet while principal forage is considered to have a great contribution to the diet selected by an animal, irrespective of its preference relative to other plant species offered. Osolo *et al.* (1996) indicated that preferred species enhance animal performance by improving the diet nutritionally while the principal species provides an animal with the opportunity to maximize intake as well as provide nutrients. Diet selection knowledge can be used in determining dietary preferences for different forage species. Tanentzap *et al.* (2009) described dietary preference as the ratio between plant species' abundance in the diet and their abundance in the grazing field. The quantity and type of forages consumed by livestock depend on different factors which can be classified as plant and animal factors. Plant factors include the plant species, crude protein level, fibre level, presence of anti-nutritive factors, external plant attributes like shininess, texture and smell. Animal factors include breed, physiological status, nutritional status, age, size and experiences early in life. Understanding why livestock eats certain plants or parts of plants allows managers to use diet selection as a feeding and pasture systems management tool. Ungar (1996) reported that knowledge of feeding behaviour is key in understanding interactions between plants and herbivores and can be used in the development of efficient pasture management systems which ultimately lead to gainful livestock enterprises.

2.3.1 Factors affecting Diet Selectivity

2.3.1.1 Type of Livestock

According to Bailey *et al.*(2019), herbivores are classified into grazers, browsers and intermediate feeders according to the animal anatomy and foraging ability. The author further noted that large ruminants are roughage eaters and have relatively large, broad mouths and greater relative rumen size than other livestock species, which allows them to use grasses efficiently. The larger rumen/reticulum of large animals promotes longer retention of food thus giving adequate time for microbial fermentation and nutrient extraction (Demment and Van Soest 1985). According to Janis and Ehrhardt (1988), variations in shape and size of muzzle relative to body size of grazing and browsing ruminants exist. The muzzle in grazers is moderately broad, a structural adaptation which favours grazing on short grass over browse species. Grazers can consume large quantities of fibrous forage since they have large rumen which can retain fibrous feed materials for long periods (Coopers, 1995). According to Van Soest (1994), the presence of large rumen in grazers is a structural adaptation which enables grazers to hold fibrous feed material for a long time thus allowing rumen microorganisms ample time to break down the feed material to release energy. Large rumen enables large ruminants to utilize fibrous feed materials efficiently more than smaller ruminants (Milne, 1991). The small pointed mouth and other dental adaptations of browsers help them select plant parts like leaves, flowers and twigs of woody species which have higher nutritional quality (Shipley, 1999). Selectivity for plant parts is higher in herbivores with small mouths compared to the species with large mouths (Jarman, 1974). For instance, the muzzle of sheep and goats are relatively small and narrow and that enables them to select plant parts with great precision compared to the large ruminants.

According to Gordon and Illius (1988), the width of the dental arcade of a foraging animal determines the animal's bite size and the precision at which selection between plants can be done. Langland’s and Sansom (1976) described the diet of browsers as more digestible and higher in protein than the diet of grazers. This may be attributed to variations in diet selection by both small and large ruminants. Langland’s and Sansom, (1976) noted that, unlike small ruminants, cattle graze less selectively and take larger bites in a way that is not conducive to selection while Lechner-Doll *et al*. (1995) found that small reticulorumen of concentrate selectors is a structural adaptation which usually enables them to select forage with low fibre, easily digestible, and rich in nutrients. For intermediate feeders, the narrow muzzle and large rumen in relation to body mass, allow them to graze selectively and still accommodate large quantities of fibre in their diet. According to Hofmann (1989) and Van Hoven (2000), intermediate feeders are classified as those which feed on a mixture of grasses and browse. Sheep are intermediate feeders and the possession of a relatively small mouth that enables them to graze close to the ground picking leaves or flowers from pastures is a structural adaptation for selection (Bailey *et al.*, 2019). Intermediate feeders are not as selective as browsers in their diet and they change their feeding behaviour according to the availability of forage –they start with young nutritious less fibre forage and as the forage ages, there is shift of feeding behaviour to selecting some parts of plants (Van Soest 1982). Owen-Smith (1999) pointed out that the amount of feed consumed by intermediate feeders and the time the feed stays in the rumen undergoing microbial breakdown is restricted by the capacities of their digestive systems.

2.3.1.2 Breed

Frost & Mosley (2020) noted that different livestock breeds vary in size and production characteristics and so is the level of their nutrient requirements thus the bigger the breed, the higher dry matter intake. The author further pointed that bigger breeds have a higher digestive ability compared to smaller breeds and that influences the choice of and proportion of forage an animal selects to include in its diet. Pearson *et al.* (2005) found that huge intake variations also occur within and between breeds. Brand (2000) noted that comparatively, Dorper sheep is a less selective grazer and it consumes more shrubs and bushes and can ingest a larger number of different plant species than Merino sheep. This makes Dorper sheep climate-smart as it can consume a wide range of feed resources, and puts on weight faster meaning it takes a shorter time to reach market weight thus giving farmers more returns within a shorter time. This means that Dorper sheep have therefore less time to emit greenhouse gasses since they reach market weight within a shorter time.

2.3.1.3 Age

Older animals have reduced metabolic rates thus their feed requirement is lower than their young counterparts and as a result, young animals spent more time aggressively foraging to meet their nutritional requirements as compared to their old counterparts (Grings, *et al.*, 2001). Tolerance to secondary metabolic substances and the degree of diet selection declines with advancement in age of the animal (Frost & Mosley 2020). In comparison to older animals, Grings, *et al.* (2001) records that young animals select diets higher in protein and energy and lower in fibre in efforts to ensure that nutritional requirements for animal growth and production as well other physiological processes are met. In search of nutritious diet, young animals may try a variety of feeds and even retry foods that once made them sick due to their limited foraging knowledge (Ralphs, M.H. and Provenza, F.D., 1999).

Animals expand their foraging and diet selection experience after weaning and so they are more willing to try a wide variety of feeds. As herbivores advance in age, wearing out of incisors teeth occur and that influences foraging and forage selection ability (Provenza *et al.*, 1992). Herbivores with worn-out teeth are not able to graze efficiently to achieve maintenance requirements. Arnold (1981) noted that a diet of a 5-month old sheep was more digestible, was higher in nitrogen content and lower in fibre, than that of older sheep. The digestive system of young growing animals are not able to handle highly fibrous feed materials thus they select diets higher in protein and energy and lower in fiber to meet the demand for rapid growth Compared with adults (Frost & Mosley 2020). In addition, the jaws of young sheep are smaller and narrow compared to the jaws of older sheep, a factor that enables young sheep to select more precisely than older sheep. Horn *et al*. (1979) found that calves selected forage with higher crude protein levels and lower acid detergent fibre (ADF) and cellulose levels than older cattle.

2.3.1.4 Body Condition

Body condition refers to the thinness or fatness of the animal and it influences the animal's foraging behaviour and hence feed intake. Feed intake in sheep decreases as the body condition improves (Frost & Mosley, 2020). Body condition score generally is negatively related to dry matter intake (Heinrichs *et al.*, 2016). Thin sheep will increase intake by 20% or more to make compensatory gain per unit live weight (Langlands, 1968). Generally, herbivores in poor body condition will eat more than those in good condition and may turn to eating poisonous or less desirable plants to increase feed intake to maintain the higher intake (Frost & Mosley, 2020). Newman *et al.* (1994) pointed out that a sheep that has been fasting will be less selective than its non-fasted contemporaries.

2.3.1.5 Stage in Production Cycle

Nutritional requirements of animals change during different life stages and they select diets based on the changes (Frost & Mosley, 2020). Lactating females require more energy and protein to meet nutritional requirements for the milk synthesis process (Hadgu, 2016). Different animal functions require energy but the amount and the level of utilization of the energy always depends on the animal energy metabolism which varies with production cycle (Schmidt-Nielsen, 1997). Certain plant species can however, be poisonous to females during gestation and can cause serious birth complications and defects, abortions or even death of the fetus thus care should be taken to prevent consumption of such plants (Stegelmeier *et al.*, 2020).

2.3.1.6 Selective Grazing

Foraging animals meet their seasonal nutritional requirements by foraging on plants and plant parts that meet the animal's nutritional requirements with minimal disruption to the functioning of their digestive systems and thus they forage species that generate comfort and avoid the ones that generate discomfort (Von & Van, 2006). Exposing animals to unpalatable feeds or feeds that because discomfort can elicit avoidance behaviour (Distel & Villalba (2018). The author further noted animals that experience a low-quality food can depress its subsequent use. Provenza *et al*. (2002) noted that when grazing animals are exposed to a variety of foods that differ in nutrients and toxins, they optimize the intake of nutrients and energy as well regulate their intake of toxins. In addition, Allen & Segarra (2001) reiterated that toxins negatively affect animal body functioning by causing reduction in DMI, limit dry matter digestibility, cause nutritional imbalance, abnormal reproduction, cause disturbance of nervous system and suppress immune system leading to disease and death. As a result herbivores forage selectively and only consume forage on plant parts and plant species that meet their nutritional requirements with minimal disruption to the functioning of their digestive systems (Von & Van, 2006). In addition, Van Soest (1982) reported that if no great quantity of any one plant is eaten, the relative amounts of poisons consumed across the spectrum of plant species will not result in dangerous levels. Further, Demi *et al*.(2021) recorded that different feeds have different taste modalities which herbivores use to evaluate the quality of food based on multiple aspects of its chemical composition and can be broadly grouped by whether they taste “good,” and therefore promote consumption, or “bad,” and therefore produce an aversive response.

2.3.1.7 External Plant Attributes (EPA)

Raufirad *et al*. (2015) reported external plant attributes (EPA) as the first plant characteristics an animal encounters when grazing in rangelands and thus they influence relative animal preference (AP) and hence selectivity. Selection of plant species by sheep is strongly influenced by plant characteristics such as leaf spines, inflorescence and stem, prehensile resistance and height of the plant (Raufirad *et al*., 2015). The author further pointed out that the position of the leaf, the succulence of the plant, the ratio of leaf to stem and the branch density of the forage species also influence selection in shoat.

2.3.2 Theoretical models that explain diet selection in ruminants

The feeding behaviour and hence diet selection of ruminants is influenced by several factors as outlined by Milne (1991). Several models and theories have been put forward to explain the process of diet selection by ruminants as detailed below.

2.3.2.1 Euphagia

The Euphagia model explains the innate ability of an animal to select a diet that will provide the nutrients appropriate to its requirements (Cooper, 1995). The existence of nutrient-specific appetite has been evident in pica which Rozin (1976) described as an innate desire by an animal to consume a specific nutrient to address a certain nutritional deficiency. This means most livestock species have the innate ability to select the appropriate diet which meets their nutritional requirements. According to Danford (1982), cattle deficient in phosphorus will show efforts to correct the phosphorus deficiency by eating bones.

2.3.2.2 Hedyphagia

According to Cooper (1995), Hedyphagia model argues that animals choose diets on a purely sensual basis. Milne (1991) indicated that selections made by sheep generally demonstrate that ruminants prefer young leafy and soft tissues rather than old, stemmy and fibrous tissues. Sheep may rely on their senses to make such dietary choices alone.

According to Distel & Villalba (2018), animals are able to associate food sensorial characteristics (taste, odour, aspect) with its post-ingestive consequences, and that this associative learning process is used to modulate preference or aversion for foods, which determines diet selection. Kilonzo (2003) reported sight as the most important sense in orienting the animal with other animals, feed resources and environment. Forbes (1995) recorded that temporary covering of the eyes does not interfere with the forage preference by grazing sheep, suggesting that they use smell, taste and tactile stimuli to discriminate between different plant species. This means that changes in the relative palatability of feed may occur when the sense of taste and smell in sheep are impaired or even removed.

Pfister (1999) pointed out that most ssecondary plant metabolites produced by most browse species may have a bitter taste or may be poisonous or may have an offensive odour which may attract herbivores to forage certain plant species or deter them from foraging other plants. Kilonzo (2003) recorded that there are special senses in herbivores that play an important role in the selection of plant species with anti-nutritive factors and thus should not be overlooked. Taste is one of the five senses that give ruminants and other animals an awareness of their environment, especially for food selection. This sense helps the sheep to recognize the saltiness, bitterness, sourness and sweetness and is often considered of paramount importance as it is the last sense in use before foods are swallowed (Cécile *et al*. 2011). It thus plays a fundamental biological role in aiding animals to regulate intake of suitable food and reject unsuitable food. Ito & Hayashi (2020) noted that animals show preference to feed with sweet taste, which are also known good sources of energy. However, they avoid bitter tasting foods because they are associated with the presence of toxins (Pfister, 1999).

2.3.2.3 Optimal foraging theory (OFT)

According to this theory, foods vary with respect to their intrinsic quality and herbivores either eat or ignore a type of food based on the quality (Provenza *et al*., 2003). Although food provides the animal with energy, searching for and capturing it requires both energy and time thus herbivores forage in such a way that they maximize energy intake per unit effort (Stephens & Krebs, 1986). This theory, therefore, explains how an animal adopts a foraging strategy that provides feed with the most benefit (energy) and at the same time uses the least energy searching for it, thus maximizing the net energy gained. Coopers (1995), noted that the process of natural selection promotes survival of genes associated with beneficial behaviour. According to Norberg (2021), optimization criterion in foraging is taken to be minimization of the daily foraging time, or equivalently, maximization of net energy gains per unit time. The author also noted large herbivores employ strategies which minimize energy expenditure during foraging but also lead to selection of diets which are high in energy. To maintain an optimal rate of energy intake, Bergman *et al.,* (2001) noted that animals move from one location to another during foraging in efforts to choose the appropriate forage.

2.3.2.4 Morphophysiology

Factors associated with an animal, such as body size, sex and breed affect diet selection. Fibrous feed resources can be utilized more effectively by large ruminants than by smaller ones (Milne, 1991). Ruminants with large rumens can hold fibrous feed materials for long periods (Coopers, 1995) thus giving rumen microbes enough time to break the fibrous material. On the other hand, browsing animals have smaller rumen which allow indigestible food particles of to flow more rapidly through the tract since most browses contain less cell wall and fibers within their cell wall are more lignified and indigestible (Shipley, 1999).

Diets with high cell contents are rich in energy and they have higher digestibility. Hofinanne (1989) classified herbivores based on such rumen morphological differences as concentrate and roughage eaters. Older animals can utilize lower-quality roughages better than younger ones even within the same species (Weston *et al.,* 1989). The width of the dental arcade of a grazing animal determines the bite size of the animal and its ability to make a precise selection between different plant species (Gordon and Illius, 1988). Coopers (1995) noted that the muzzle of sheep is relatively narrow and therefore enables them to select plant parts with great precision. There is ample evidence that morphological and physiological attributes of animals influenced diet selection as reported by Coopers (1995). However, individual animals have genetic variations in their ability to tolerate materials such as anti-nutritive factors (Provenza and Balph, 1990). Such variations between individual animals may affect diet selection and thus lead to variations in the diets selected (Provenza and Balph, 1990).

2.3.2.5 Learning through consequences

This model explains how pre-ingestive experience and post-ingestive consequences affect dietary preferences and it is developed through interactions with other animals or through applying trial and error method on the diets (Villalba & Provenza, 2009). Herbivores exposed to varied diets may also learn about the benefits of specific plant secondary compounds for alleviating certain maladies (Villalba *et al.,* 2010). Through natural selection, animals have developed the ability to learn about foods (Provenza and Balph, 1990). According to Chapple and Lynch (1986), sheep will start eating any new food by ingesting small quantities of the new food and will continue increasing the amounts consumed slowly by slowly as long as there are no adverse effects caused. According to Thorhallsdottir *et al.* (1990), lambs demonstrate taste aversions when they watch and preferably participate with adult role models or contemporaries that have developed aversions. In addition, Thorhallsdottir *et al.* (1990) noted that the taste aversions are stronger if the lambs are learning from their mothers but this does not mean that the lamb and the mother (role model) will automatically select the same plant species. Lambs also learn such associations by trial and error as indicated by Burritt and Provenza (1989). There is ample evidence to show that sheep can remember foods that caused adverse consequences (Burritt and Provenza, 1991). However, forming an association between the foods ingested and the consequence that occurs as a result of its ingestion would not determine subsequent dietary choices (Cooper, 1995). The feeding behaviour of sheep and other animals foraging in a complex environment may not be accounted for when a single model is used thus a better understanding of how sheep and other animals select their diet would therefore be gained by applying a mix of these theories (Cooper, 1995).

2.4 Feed intake

Voluntary feed intake is defined as the amount of feed ingested at a specific time when feed is freely accessed by the animal. Coleman and Moore (2003) indicated that voluntary feed intake is important in determining the quality of feed and is an accepted indicator of determining the potential performance of an animal. According to Schülke *et al.* (2006), animals select feed depending on factors associated with the animal, environment and the feed itself.

2.4.1 Animal factors influencing diet intake

2.4.1.1 Body size

There is a relationship between voluntary feed intake and body size and metabolic body size of the grazing animal (Lewis & Emmans, 2010). According to Glazier (2008), an animal's body size influences intake through its metabolism. The energy demands of an animal can be calculated as the body weight of the animal raised to power 0.75 (Klieber, 1961). This means that the energy required by an animal per unit weight is greater in smaller animals because they have a large surface area to volume ratio compared to large animals. Despite *ad libitum* intake being proportional to metabolic size, Andreini *et al.* (2020) found that variations may occur in the *ad libitum* intake due to variations in feed digestibility. Different breeds of livestock have different body sizes and hence different production characteristics. The differences in body size and production characteristics can be explained in terms of differences in nutrient requirements, dry matter intake, and digestive ability. Glazier (2015) indicated that larger organisms have lower mass-specific metabolic rates than smaller organisms meaning there is a negative correlation between body mass and metabolic rate. The author further reported that increasing body weight results to a concurrent decrease in daily food intake.

2.4.1.2 Physiological status

An animal's physiological requirements determine the level of voluntary feed intake. Forbes (2007a) indicated that lactating animals increase their intake to cover additional nutrients requirement for lactation thus satisfying the increased nutrient demand without using their body reserves if good quality feed is offered. According to Forbes (2007a), lactating cows require five times more nutrients for lactating function as required for maintenance requirement. Hunte and Siebert (1986) reported that lactating cows consume more feed than their non-pregnant and non-lactating counterparts. Hutton (1963) pointed out that even in the same flock, a lactating ewe requires 25 to 50% more dry matter intake than non-lactating ewes. Rosiere *et al*. (1980) reported that a dry 2 years old heifer consumed only 67% as much forage as that consumed by 2 years old lactating. McDonald *et al.* (2002) noted that animals in early pregnancy have a higher feed intake for the supply of additional nutrients as a result of increased demand for nutrients for fetal development. However, as pregnancy advances, feed intake reduces due to reduction in the volume of the abdominal cavity due to expansion of the uterus. Hadgu (2016) noted that pregnant ewes bearing single pregnancy have increased intake compared to ewes bearing twins and reduction in intake occurs as the ewes advance to late pregnancy.

2.4.1.3 Body Condition

Body condition refers to the thinness or fatness of the animal and it influences the animal's foraging behaviour. According to Tolkamp *et al.* (2006), intake of hay as well as of pelleted feeds by a sheep with a given body weight is affected considerably by the animal's fatness. As a thin sheep becomes fat, feed intake declines thus body condition score is negatively related to dry matter intake (Heinrichs *et al.,* 2016). Langland (1968) indicated that when a thin and a fat sheep graze together, the thin sheep will compensate in terms of weight gain by increasing feed intake by 20% or more per unit of live weight. Feed intake in malnourished and thin herbivores is generally higher than the intake in animals in good condition. Due to high intake in animals with poor body condition, it is possible that when forage is limited, they may turn to feed on poisonous or less desirable plants to maintain the higher intake (Frost & Mosley, 2020). Yarahmadi *et al.* (2021) showed that starved sheep had the highest compensatory growth and lean meat. Further, the author noted that starved lambs were preferable due to higher ADG, better FCR, and more suitable carcass traits, as well as the higher percentage of lean meat than unstarved sheep. Compensatory growth is shown by the ability of animals previously restricted in feed or nutrient intake to outgain their better counterparts when given free access to good quality feed (Greeff *et al.*, 1991).

2.4.1.4 Growth and Age

Hadgu (2016) explained that the need for body tissue formation could lead to high intake in growing animals. Lewis & Emmans (2010) also noted that feed intake in a growing animal changes as its size increases. According to Forbes (2007a), sufficient and high-quality food should be fed to growing animals to attain their potential growth rate. A study by Hunte and Sieber (1986) showed a decline in feed intake per unit body weight as age and live weight of steers increase. The effect of feed intake on compensatory growth was reported with variations which may be attributed to the type and breed of animal, type and composition of feed, length of restriction duration and environmental factors Lawrence & Fowler (2002).

2.4.1.5 Forage preference

Milford and Minson (1966) reported that dry matter intake was higher when ruminants were offered hay from different grass species in choice feeding than when fed with hay from one grass species. Intake of broad-leafed plants can differ from the intake of grasses. Considerable evidence from research indicates that animals have a higher intake of legumes than grasses even when the digestibility is comparable (Ulyatt, 1981). The extent to which an animal has interacted with a certain feed can also affect intake. Arnold (1970) indicated that feed intake in a sheep which is inexperienced on a pasture and the environment may be depressed by 50% for up to 10 months.

2.4.1.6 Competition

Presence of competition for feed and feeding space has a major influence on feeding behaviour and rate of eating (Van, 2006). Feed intake is generally considered to increase when there is competition among animals. Keeping animals in a group provides an opportunity for social interactions between animals and also increases the total available space (Von & Van, 2006). Total DMI increases linearly as the number of animals in a pen increases. Domanski *et al.* (1971) found that sheep feeding in smaller groups showed a poorer growth rate than those feeding in larger groups. The author further pointed out that sheep in smaller groups spent less time grazing than sheep in larger groups and the reason was suggested to be that sheep in large groups might benefit from social facilitation and/or from the increased number of individuals that are aggressive. Similarly, animals in the pens with more animals drank more water than those in the pens with one animal (Hadjigeorgiou *et al.,* 2003). The author further recorded that increased animal group size increases feed intake leading to increased water intake. Thus the factor affecting feed and water intake in this case is obviously competition which intensifies as the number of animals increases.

2.4.2 Factors associated with the feed

Both physical and chemical feed factors have different effects on feed intake depending on the animal species and age. For example, ruminants can eat and digest bulky feed material because they have the capacity and ability due to rumen microbes. Young animals like calves, piglets, lambs and kids can only be able to handle liquid feed materials until the digestive system is more developed. Feed factors affecting feed intake include smell and taste of the feed, quality of feed, digestibility of the feed, level of concentrates fed, bulkiness of the feed, the physical state of feed, presence of toxins and acidity of the feed. Van Soest (1994) mentioned that different plants have different defense mechanisms against herbivores and as a result, herbivores have developed the ability to manipulate and overcome these defenses and consume plant species. Gowda (1996) reported low intake when goats were browsing on species that had thorns, spines or prickles compared to those that were spineless. Feedstuff that digests slowly remains longer in the rumen leading to reduced intake. According to Lechner Doll *et al.* (1995), high-quality food is relatively rapidly digested and as it stimulates more food intake as it passes down through the digestive system of the animal thus improving animal productivity. Welch and Hooper (1988) reported that animals will not graze where there are manure deposits unless no other feed is available. This unacceptability might be due to the smell or taste of the grass that is closely associated with the dung pad.

2.4.2.1 Supplementation

Protein supplementation is associated with increase in intake and is generally attributed to increasing rumen microbial activity and consequently rate of passage. Tahir (2008) found that addition of Starch to a roughage diet is thought to affect dry matter intake in a negative way in lactating dairy cows. Shibeshi *et al.* (2022) recorded that Sheep supplemented with the higher level of lablab hay had higher total intake compared to those offered with the low level of lablab hay supplementation. Supplementation with forage legumes at low levels in ruminants feeding increases the efficiency of utilization of low CP containing basal feeds, such as straws (FAO, 1997). According to Van Soest (1995) diet crude protein concentrations below 7% do not meet the nitrogen needs of rumen microbial populations and therefore lowers digestibility and hence forage intake. Van (2006) recorded that concentrate added to roughages of low digestibility tends to be consumed in addition to the roughage since supplementing of concentrate stimulates micro-organism function in the rumen, reduces retention time and thus increases the intake of poor quality feed.

2.4.2.2 Forage availability

Adequate access to feed allows animals to eat sufficient in order to satisfy the animals appetite and meet its production nutrient demand (Barber *et al.,* 2010). Allison (1985) reported that the rate of forage intake is closely related to forage availability thus feed consumption increases with increase in forage availability. The author also pointed out that changing forage availability can be maintained by altering the grazing time such that as the forage decreases, the grazing time increases thus increasing forage intake.

2.4.2.3 Grazing intensity

Grazing intensity affects animal performance. Allison (1985) reported that as grazing intensity increases, chances for livestock to graze selectively decline due to increased removal of the preferred grass species and plant parts. High grazing intensity limits availability of herbage and therefore lowers the quality of forage available for grazing. This may be due to a reduction in the opportunity for selective grazing. According to Allison (1985), low grazing intensity can lead to overgrown plant parts which become more fibrous thus resulting in declined digestibility and nutrient levels.

2.4.2.4 Particle size of feed

Chopping feed into small pieces reduces fibre length and the animals have less opportunity to select between the different parts of the feed (Van, 2006). This leads to increased feed intake and reduced time for eating. However, when grass or hay is offered in long, unchopped form the animals have more opportunity to select between stem and leaf, which leads to increased nutritive value of the feed consumed and increased time for eating (Van, 2006).

2.4.3 Factors associated with the Environment

2.4.3.1 Environmental temperature

Both high (heat stress) and low (cold stress) environmental temperatures can affect intake in farm animals(Hadgu, 2016). Heat stress lowers animal performance by reducing feed intake thus lowering heat production that results from the activities associated with feeding (West, 2003; Morrison, 1983). Forbes (2007a) noted High temperatures reduce grazing intensity through thermostatic voluntary feed intake control. The author further pointed out that animals reduce their feed intake if body temperature rises above the thermo-neutral zone to avoid excess heat that results from activities of feeding, digestion, absorption and metabolism. However, animals increase feed intake when the temperature is below the thermo-neutral zone, in order to produce heat to maintain homeothermy (Forbes, 2007a). As a way of increasing intake, animals change their grazing behaviour to rest during the day when temperatures are high and graze in the evening when temperatures are relatively low. Prolonged drought, or cold stress may lower immune system of animals thus making them less resistant to disease, parasites, or infections (Tolleson, 2020). High temperature and humid conditions are conducive to proliferation of fungi and bacteria and other pathogens and ecto- and endo parasites which could affect feed intake by obstructing digestion (Parkins and Holmes, 1989).

2.4.3.2 Housing

Shade reduces the impact of heat stress in hot climates and therefore increases intake (Forbes, 2007a). Shade also reduces adverse effects of solar radiation like skin cancer and photosensitive disorders in some animals in hot environments. The effect of heat stress is more serious in tropical regions than in temperate regions thus provision of shade in tropical regions is more advantageous (Hadgu, 2016). Artificial structures may be made to provide shade where natural shade is lacking in order to reduce heat stress in animals thus increasing intake and performance. The effect of heat stress on animal physiology and behaviour may change from time to time depending on variations in climate and weather. Muller and Botha (1994) reported higher feed intake in cows provided with shade than in cows without shade.

2.4.3.3 Disease, Disorders and Parasites

Reduced feed intake is one of the first signs of many diseases (Forbes, 2007a). Diseases can cause hock lesions and joint pains of the limbs thus affecting movement of animals and their ability to forage hence they lose body condition class over time due to changes in feeding habits or intrinsic pain affecting feed conversion (Sadiq *et al.,* 2017). Nutritional diseases and deficiencies of some nutrients reduce appetite in animals thus reducing feed intake. Protein deficiency, Mineral imbalance and deficiency of some vitamins like A and K lead to loss of appetite and reduced feed intake (Hadgu 2016). Diseases and disorders affecting the sight of the animal reduce feed intake by interfered with the visibility of feed while aching teeth and jaw pains affect foraging and mastication thus reducing feed intake (Margaret *et al.,* 2002). Animals infested with internal parasites have reduced feed intake but the level of reduction depends upon the severity of the infestation (Eisa *et al*., 2017; Parkins and Holmes, 1989). Parasites could affect feed intake and animal performance by reducing rumen pH, depressing rumen motility, changing the level of hormones and impairing feed digestion, energy and nitrogen utilization (Hadgu, 2016). Forbes (2007a) indicated that sheep infested with helminths have a depressed feed intake and this can be attributed to continuous stimulation of receptors in the gastrointestinal tract wall by parasites.

2.4.3.4 Availability of water

Both the amount of water available and the time of water intake is closely related to food intake (Forbes, 2007a). Inadequate water intake reduces feed intake as water is involved in the processes of food nutrients digestion and metabolism. Water intake is high when animals eat dry feeds and when the environmental temperature is high. Prolonged dry season is characterized by water scarcity which leads to long trekking distances by animals and thus energy that would have otherwise gone to production function is diverted to trekking function. Inadequate and irregular water intake by animals affects body functions such as lacto-genesis, egg formation and calf development.

2.5 Live weight gain (LWG)

Growth is often described as the increase in weight per unit of time. The efficiency at which sheep convert feed to live weight influences profitability. Köksal *et al*. (2000) described feed conversion efficiency (FCE) as the change in live weight divided by feed consumed for a specific period. Alfa *et al.* (2016) noted that an animal that puts more weight using less feed is considered an efficient converter of feed compared to animals with lower FCE if the feed is of similar quality.

2.5.1 Factors affecting Live Weight Gain (LWG)

2.5.1.1 Genetic

Sheep with the genetic potential to put on more weight faster will also utilize and convert feeds more efficiently than slow growing sheep as reported by Aziz *et al.* (1995). He also reiterated that fast growing lambs ate more than their slow growing counterparts and that individual selection could be an appropriate selection method for animals with better feed conversion efficiency, lower feed intake and higher weight gain. Malik *et al.* (2019) noted that growth rate and feed conversion efficiency of an animal declines as age advances. He also observed that male lambs gained more than female lambs when kept in the same environment and subjected to the same management.

2.5.1.2 Quality of feed

The quality of feed offered to the sheep dictates intake levels and live weight gain (LWG). Mayulu (2016) reported that highly nutritious and palatable feed is eaten more and results in weight gain in livestock. The quality and quantity of feed vary in both spatial and temporal aspects during the year. Adequate feed resources of good quality are observed during the wet season when the sheep gain more weight than during the dry season. Khan and Habib (2012) noted that the nutritive value of common pasture species during the dry season has CP content averaging less than 7% which results in low live weight gain due to low intake of CP.

2.5.1.3 Diseases

Diseases affect the general well-being and performance of animals. Diseases lead to lack of appetite and thus low feed intake resulting in low weight gain since the animal doesn't get enough nutrients required to maintain different body functions. Lambs infested with internal parasites have low live weight gain as Eisa *et al*., (2017) and Mackay *et al*. (1998) reported. Kirkwood (1980) noted a 53% reduction in growth rate in lambs with sheep scabs. According to Adams (2002), low growth rate in lambs may be due to parasite infestation or a condition of the ewe that affects milk production or forage supply. Trials by Nieuwhof *et al*. (2008) showed that animals with average foot rot suffered weight loss of 0.5 to 2.5kg live weight. External parasites will cause stress to animals which affects intake and hence weight gain. Diseases and disorders affecting the buccal cavity will interfere with prehension and mastication of feed thus reducing feed intake and resulting in low weight gain.

2.5.1.4 Environment

Environmental variables such as temperature, rainfall and humidity affect weight gain either by affecting the availability of feed or the level of feed intake by the sheep or the utilization of the feed consumed (Rojas-Downing *et al.,* 2017). According to Tahuk *et al*.(2018), rainfall affects the availability and quality of feed resulting in higher average daily gain (ADG) in the season with adequate and quality feed. Mallick *et al.* (2019) reported higher ADG in Deccani sheep lambs born in India during November to February and March to June seasons when forage is adequate. High temperatures depress weight gain due to depressed growth which is caused by decreased voluntary feed intake. In the heat of the day, feed intake is controlled by thermostatic control and the animal may feel as if it has taken enough while it has not. The overall effect of this is a decline in weight gain (Rojas-Downing *et al.,* 2017).

2.5.2 Importance of live weight measurement in sheep production

Live weight measurements can be used as a management tool in different aspects of livestock production (Wamatu & Alkhtib, 2021). Sheep breeders use information on live weight to select animals for breeding (Jawasreh *et al.*, 2018), animal health managers use live weight to determine dosage rate when administering drugs (Keegan *et al.,* 2018). Other management decisions like marketing, feeding and breeding are also based on the live weight information of the sheep. Alfa *et al*. (2016) described the use of live weight measurements in the calculation of feed conversion efficiency (FCE) which is the measure of how efficiently an animal can convert different feeds into meat or milk. Köksal *et al*. (2000) described the formula for measuring feed efficiency as the change in live weight divided by feed consumed for a specific period. Feed conversion ratio (FCR) is the inverse of feed efficiency and is expressed as a ratio of feed consumed to weight gain over the entire period the feed is given. Alfa *et al*. (2016) indicated that sheep and cattle will require more than 8 kg of feed to put on 1 kg live weight thus their FCR is 8:1. The FCR tends to be higher in older sheep than in young ones. Alfa *et al*. (2016) gave an example that 8 months old lambs have a higher FCR than 4 months lambs. Animals with low FCR are considered efficient users of feed compared to animals with higher FCR if the feed is of similar quality (Alfa *et al*., 2016). Malik et al. (1996) reported that FCR for lambs fed high-energy diets was lower than FCR for lambs fed low and medium-energy diets.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

The study was conducted at the Machakos Agriculture Training Centre (ATC) farm in Mua ward, Machakos County, Kenya. The farm is located six kilometers from Machakos town, next to the Machakos people's park, at latitude S1^{o}32' 43.8108" and longitude E37^{o}14' 26.124" at an altitude of 1600 meters above sea level. It has a minimum and maximum temperature of 13.7^{o}C to 24.7^{o}C, respectively. The predominant soils at the site are well drained sandy clay loams, with acid humic top soil of volcanic origin, (Jaetzold *et al.*, 2006). The site was selected because of its accessibility, the availability of a permanent housing facility for the sheep, constant supply of tapped water, electricity, and security. Both the diet selection experiment and the intake and weight gain experiment were done on the same site.

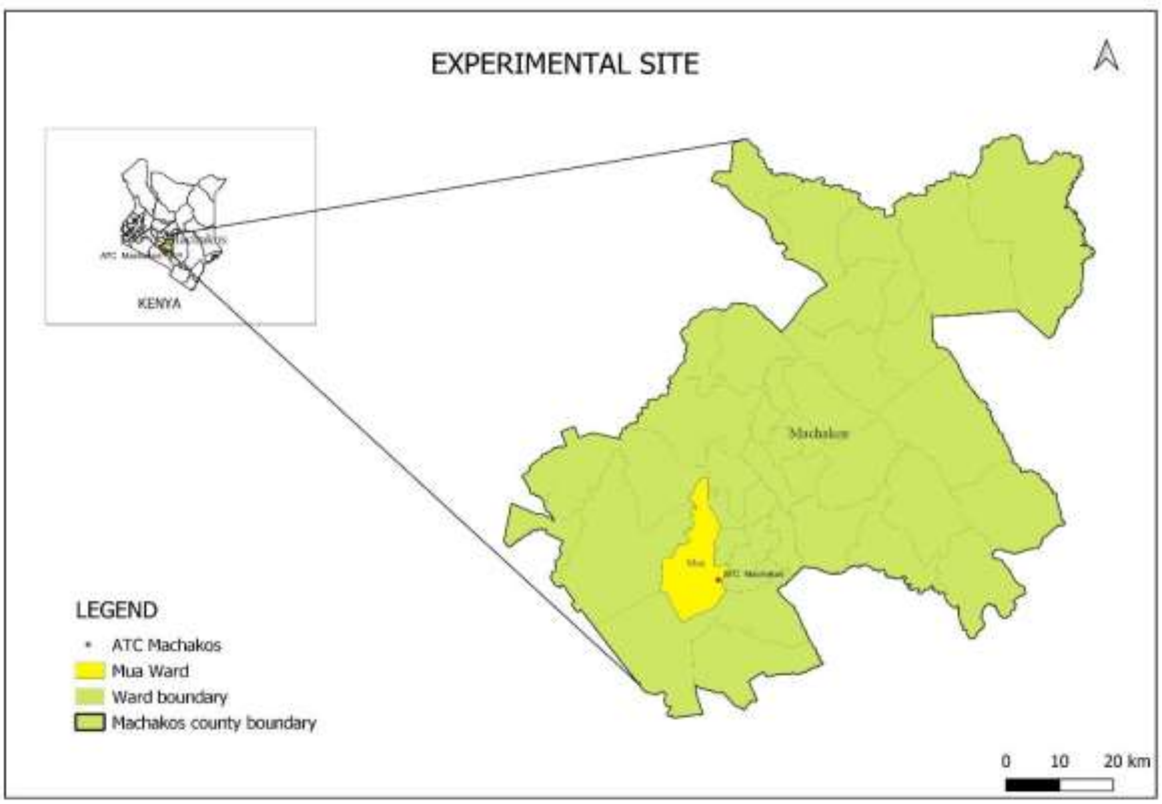

Figure 3.1: Map of Machakos County showing the study area

3.2 Experimental feeds

Six grass species, two humid and four semi-arid, were used in the experiment. *Brachiaria decumbens* cv. Basilisk and *Chloris gayana* were the humid grasses, while *Cenchrus ciliaris*, *Chloris roxburghiana*, *Enteropogon macrostachyus*, and *Eragrostis superba* were semi-arid grasses. The choice of different grass species in this study was done to represent different grazing conditions. All grasses were sourced from farmers who were organized in a community-based organization (CBO) for pasture production in Kibwezi East sub county, Makueni County. The farmers were well trained on pasture establishment and management by the Kenya Agriculture and Livestock Research Organization (KALRO), Kiboko. The grasses were regrowth from the October, November and December (OND) 2019 rains and were harvested in March 2020 using sickles. The grass was dried separately under shade for three days, after which each grass was baled separately using manual hay box balers. Hay from various types of grass was labelled and transported to the experimental site, where it was stored in a well-ventilated store until July 2020, when the experiment began. The experiment period was from July to October 2020.

Plate 3.1: Plot of *C. gayana* grass

Plate 3.2: Plot of *E. superba* grass

Plate 3.3: Plot of *E. macrostachyus* grass

Plate 3.4: Plot of *C. roxburghiana* grass

Plate 3.5: Plot of *B. decumbens* grass

Plate 3.6: Plot of *C. ciliaris grass*

3.3 Experimental animals for diet selection study

Five healthy uncastrated male Dorper sheep aged 12 months old and of average body weight 27.5±1.12 kg were selected from a flock of 70 sheep, and inspected by a veterinary surgeon for any abnormality before delivery to the experimental site for use in the diet selection study. Sheep age was determined through dentition as Casburn (2016) described. The choice of an uncastrated sheep aged 12 months was to ensure uniformity in the foraging experience. All the sheep were sourced from the same ranch in Machakos County, and were therefore assumed to have been exposed to similar feeding conditions and experiences. The sheep were transported in an open van to the experiment site where they were treated for internal and external parasites using Ivermectin prior to the start of the experiment.

Plate 3.7: Central herd where experimental sheep were selected

Plate 3.8: Age determination using dentition of sheep

3.4 Housing, feeding and watering facilities for diet selection study

Each sheep was housed individually in a pen of dimensions 3x3m. The pens were well ventilated and illuminated by daylight. The floor was cemented and wood shaving was used to cover the floor for insulation. Wood shaving was chosen to cover the floor because it is not eaten by the sheep and it is a good absorbent. The pens were cleaned twice every week and the wood shaving was replaced after every cleaning. The sheep pens were disinfected prior to the introduction of the sheep. A foot bath was placed at the main entrance for the entire period of the experiment so that people entering the unit could disinfect their feet. Each pen was fitted with six removable feed troughs so that each trough contained a single feed. The troughs were improvised by cutting a 20-litre plastic water container above the center. The feeders were removable to allow easy emptying of uneaten grass into the weighing bucket. A water trough was placed in one corner of each pen. All troughs were of the same colour for consistency and to avoid any effect of colour on the choice of food.

Plate 3.9: Set up of housing feeding, watering **a**nd installed CCTV system**.**

Plate 3.10: Feed intake data collection.

3.5 Diet selection and intake study

A diet selection and intake study was conducted in a cafeteria feeding system as described by Larbi *et al*. (1993a). The study lasted for 33 days where 28 days were for acclimatizing the sheep to the experimental feeds and environment and 5 days were for data collection. Hay from six experimental grass species described earlier was chopped separately into small uniform pieces using a grass chopper and each was placed in a separate trough. Each sheep was offered experimental feed at 3% of body weight for each of the chopped grass species. The experimental feed for each day was divided into two equal portions in order to feed the sheep in two regimes daily; the first regime was between 0830 hours to 1330 hours while the second regime was between 1430 hours to 1830 hours. The feed troughs were randomized daily to avoid the "habit reflex" by the sheep as described by Kaitho *et al*. (1996). Each sheep was allowed to eat any of the grasses from six different feed troughs. Clean drinking water and mineral supplements were offered *ad libitum* throughout the selection and intake experiment.

3.5.1 Diet intake data collection

The amount of uneaten feed was subtracted from the amount of feed offered to the sheep for each feeding regime described in section 3.5. The difference for the two regimes were added and recorded daily for each sheep and then averaged for the five days of data collection. Feed intake was calculated as 85% of the average computed difference. The 15% of the computed difference was the estimated wastage of grass that occurred during the feeding process and was calculated as the average weight of the spilled grass expressed as a percentage of the average computed difference. Data on time (seconds) taken by sheep eating a particular grass and the number of feed visits was recorded using Closed-circuit television (CCTV) cameras system for each feeding regime. Average time (seconds) each sheep took eating a particular grass and the average number of times each sheep visited a particular feed was calculated for the two feeding regime for five days. Feeding time and number of feed visits by the sheep for each grass was then computed as the average for the five days the data was collected.

3.5.2 Selectivity index

Selectivity index is the proportion of one forage in the diet of an herbivore relative to its proportion in the sward (Zhang *et al*., 2022). 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 as described by Gallardo *et al*. (2014) as $S_i=(r_i-p_i)/(r_i+p_i)$

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 (Hejcmanova *et al.*,2019) with the S_i values ranging from -1 to +1. A Selectivity index (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 grass consumption was in proportion to its abundance or availability (Gallardo *et al.,* 2014). Four treatment diets in the diet selection experiment (the most preferred, the least preferred and two moderately preferred grasses) were chosen for the intake and weight gain experiment.

3.6 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 and constituted for analysis as described by Njarui *et al*. (2016). The samples were milled using a Willey mill to pass through 1.0 mm Screen. The samples were then analyzed for chemical composition in triplicates at the Animal and Nutrition Laboratory at the University of Nairobi, College of Agriculture and Veterinary Services, Kabete. Chemical components such as crude protein (CP), total ash, ether extract (EE), crude fibre (CF) and nitrogen-free extract were determined by standard methods (AOAC, 1990). Fibre components which include Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) were determined according to Goering and Van Soest (1970). The extent of *in vitro* organic matter digestion (IVOMD) was determined using the Tilley and Terry (1963) two-stage method which involved 48-hour fermentation by rumen micro-organisms followed by 48-hour hydrochloric acid pepsin digestion. Calcium was determined using atomic absorption while phosphorus was determined using UV-visible calorimetric method (AOAC, 1984).

3.7 Diet intake and live weight gain study

Sixteen male growing Dorper sheep aged between 12 months and 18 months and weighing between 18-29 kg were used in the diet intake and weight gain study. The sheep were selected from a central herd and were grouped into four groups each with four sheep. The sheep in all the four groups were balanced for both age and weight as described by Njarui *et al*. (2016). Each group was randomly allocated one of the four treatment diets chosen earlier in the diet selection study (the most selected, the least selected and two moderately selected grasses). Each of the four sheep in a group was a replicate and was housed in an individual pen (Kaya, 2011). Feed and water troughs were improvised as described in the section for housing, feeding and watering facilities above. The experimental diets were offered at 3% of the sheep's body weight on a dry matter basis. The sheep were allowed 14 days for acclimatization to both the environment and experimental feeds. A known quantity of each of the four selected grasses was put in four different feed troughs placed in trough holders in the individual pens for the sheep. The grasses were offered in the morning and added in the afternoon to ensure feed availability at all times. The remnants were removed, weighed and recorded the following day before any new feed was offered (Njarui *et al.*, 2016). The difference between the amount of feed offered to individual sheep and the amount of uneaten feed in the trough was computed and recorded daily less 15% of the difference. The 15% was the estimated average feed wastage during the feeding process determined by collecting and weighing the grass spilled outside the trough in individual pens expressed as a percentage of the computed difference.

The initial live weights of the sheep were taken after the two weeks acclimatization period and the subsequent weights were taken on a weekly basis. The weights were taken in the morning before any feed was given to determine changes in live weight (Okoruwa, 2019). The study took 56 days with 14 days of acclimatization to the diet and environment and 42 days for data collection. Final body weights were taken and recorded. Total weight gain was computed as the difference between final weight and initial weight while total feed intakes were determined by adding the daily feed intake for the entire period of the study. Average daily gain (ADG) was calculated as the total weight gain divided by the number of feeding days (Hassen & Ali, 2019).

3.8 Data analysis

Data on time spent feeding, dry matter intake, number of times a particular grass was visited and the selectivity indices (SI) in the diet selection study were tested for normality using the Shapiro-Wilk test in order to determine the appropriate statistical analysis method to use. The sample was small ($n<50$) and therefore Shapiro-Wilk test was appropriate to test for normality since it has more power and is the most popular and widely used method to detect non-normality (Mishra *et al.*, 2019). The distributions were non-normal ($p<0.05$) for data on time taken on feed ($W = 0.5794$, $p =<0.0001$), data on the number of feed visits ($W = 0.8570$, $p =0.0009$), data on dry matter intake ($W = 0.5909$, $p =<0.0001$) and data on SI ($W=0.8229$, $p=0.0002$) according to Shapiro-Wilk tests, where 'W' is the Shapiro- Wilk statistics test value. Based on this outcome, the data was $\log_{10}$ transformed and a normality test was performed again on the $\log_{10}$ transformed data.

A Shapiro- Wilk test on the $\log_{10}$ transformed data did not show evidence of non-normality ($p>0.05$) for time spent on feed (W = 0.9481, p = 0.1499), number of feed visits (W = 0.1473, p=0.0941), dry matter intake (W = 0.9419, p =0.1020) and for SI (W=0.9505, p = 1752). The transformed data for the time taken, dry matter intake, number of trough visits and selectivity index was subjected to Analysis of Variance (ANOVA) in a completely randomized design (CRD) with the six types of grass as the treatments and the five sheep as the replications using (SAS, 2000) to test the effect of grass species on diet selectivity and intake by sheep. Where the means were significantly different, Least Significant Difference (LSD) method was used to compare means at 5% probability level (Steel and Torrie, 1980). T-test was used to test the effect of grass category (humid and semi-arid) on diet selectivity. Although $\log_{10}$ transformed data was used in the analysis, the results were presented based on the non-transformed means.

Data on feed intake and weight gain for intake and live weight gain experiment was analyzed using general linear model (GLM) of SAS, 2000 to determine the effect of different grasses on selectivity index, intake and weight gain. Where the F-test was significant, means were compared using Tukey at 5% probability level. Data was analyzed based on the model below:

$$Y_{ij} = \mu + T_i + E_{ij}$$

Where: Y_{ij} is the j^{th} observation of the i^{th} treatment (dependent variable).

μ is overall mean (constant/intercept), T_i is the effect of the i^{th} treatment.

E_i is the error associated with i^{th} treatment.

Pearson correlation analysis was used to test the relationship between crude fibre, crude protein, average daily weight gain, dry matter intake, selectivity index, and *in vitro* dry matter digestibility.

CHAPTER FOUR

4.0 RESULTS

4.1 Diet selection and intake

Results of one-way ANOVA on $\log_{10}$ transformed data in the current diet selection and intake study showed a significant difference in selectivity index and dry matter intake (p=<0.0001) between the grasses. Similarly, time spent by sheep and the number of feed visits differed significantly (p=<0.0001) for different grass species (Table 4.1).

Table 4.1: Mean (±SE) dry matter intake, mean (±SE) feeding time, mean (±SE) number of grass visits and mean (±SE) SI for different grasses fed to sheep.

Grass species	DMI	FT	NV	SI
E. macrostachyus	$635^{a} \pm 27.70$	$2924.2^{a} \pm 213.46$	$3.7^{a} \pm 0.27$	$0.6^{a} \pm 0.01$
C. ciliaris	$84.2^{b} \pm 11.68$	$255.7^{b} \pm 95.81$	$2.0^{ab} \pm 0.28$	$-0.3^{ab} \pm 0.06$
E. superba	$55.6^{c} \pm 20.14$	$270.9^{b} \pm 131.79$	$1.4^{bc} \pm 0.48$	$-0.5^{bc} \pm 0.15$
C. gayana	$28.8^{c} \pm 7.14$	$61.5^{c} \pm 25.91$	$0.7^{cd} \pm 0.18$	$-0.7^{cd} \pm 0.07$
C. roxburghiana	$16.4^{cd} \pm 6.35$	$11.1^{d} \pm 5.69$	$0.3^{de} \pm 0.07$	$-0.8^{de} \pm 0.07$
B. decumbens	$10.8^{d} \pm 3.22$	$8.2^{d} \pm 3.61$	$0.2^{e} \pm 0.07$	$-0.9^{e} \pm 0.03$
Mean	138.5	588.6	1.37	-0.41
SEM (P<0.05)	41.88	199.23	0.242	0.1
F Value (5,24)	20.41	24.85	11.39	12.62
P-Value	<0.0001	<0.0001	<0.0001	<0.0001

a, b, c, d, e Means with different superscripts in the same column are significantly (p<0.05) different.

Key: SI= Selectivity index, SE = Standard error of mean, DMI=Dry matter intake (g/day), FT= Feeding time (Seconds), NV =Number of feed visits.

Dry matter intake in the current study was highest for *E. macrostachyus* and lowest for *B. decumbens.* Similarly, the sheep spent most time eating *E. macrostachyus* grass while the least time was spent on *B. decumbens* grass. The study also showed significant difference in dry matter intake (p=0.0165), time taken eating (p=0.0192), number of visits (p=0.0005) and selectivity index (p=0.0007) between semi-arid and humid grass species (Table 4. 2).

Table 4.2: Mean (±SE) dry matter intake, mean (±SE) feeding time, mean (±SE) number of visits and mean (±SE) SI value for humid and semi-arid grasses categories fed to Dorper sheep

Grass category	**DMI**	**FT**	**NV**	**SI**
Semi-arid	191.1 ± 58.78	865.5 ± 280.56	1.82 ± 0.314	-0.23 ± 0.13
Humid	19.8 ± 4.76	34.8 ±15.20	0.47 ± 0.117	-0.77± 0.0483
Mean	138.59	588.6	1.37	-0.41
SEM	41.88	199.23	0.241	0.1
t value	-2.74	-2.97	-4.03	-3.87
DF	28	28	23.7	23.6
p<0.05	0.0106	0.006	0.0005	0.0007

Key: SI=Selectivity index, DMI=Dry matter intake, FT= Feeding time, NV =Number of feed visits.

The results show higher (p<0.05) DMI for semi-arid category (191.1) than the humid category (19.8). This could be attributed to differences in nutritive value of grasses categories due to different ecological adaptations. In the current study, humid grasses were grown in semi-arid conditions and since they are not adapted to high temperatures semi-arid conditions, they had more fibre deposits which led to the low intake (Njarui *et al.*, 2016). As a result, the sheep selected semi-arid grasses more than the humid grass species (plate 4.1 and plate 4.2).

Plate 4.1: Diet selection process.

Plate 4.2: observation of diet selection

4.2 Chemical composition and *in vitro* dry matter digestibility of grasses

The results of ANOVA showed differences ($p<0.05$) in grass chemical components (DM, ASH, CP, NDF, ADF, ADL, Ca, P) and *in vitro* dry matter digestibility (IVDMD) between the six grasses (Table 4.3).

Table 4.3: Chemical components (g Kg^{-1}DM) and *in vitro* digestibility (g Kg^{-1}DM) of the six grasses used in the experiment.

Grass	ASH	CP	NDF	ADF	ADL	IVDMD	Ca	P
E. 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}
C. 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}
C. 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}
B. 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}
E. 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}
C. 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	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

$^{a, b, c, d}$ Means bearing different superscript letters in the same column are significantly different ($p<0.05$). SEM=Standard error of means.

4.3 Selectivity index, dry matter intake and live weight gain

Results of the current study showed difference ($p<0.05$) between dry matter intake and live weight gain as well as selectivity index among sheep fed different grass species (Table 4.4).

Table 4.4: Mean (± SE) selectivity index, mean (± SE) dry matter intake and mean (± SE) average daily gain of sheep fed on selected grasses.

Grass	SI	DMI (g $Sheep^{-1}$)	ADG (g $Sheep^{-1}$)
E. macrostachyus	$0.6^{a} \pm 0.01$	$671.8^{a} \pm 16.005$	$25.99^{a} \pm 3.754$
C. ciliaris	$-0.3^{a} \pm 0.06$	$652.56^{ab} \pm 18.259$	$24.55^{a} \pm 4.283$
C. gayana	$-0.7^{b} \pm 0.07$	$598.86^{bc} \pm 16.131$	$18.66^{a} \pm 3.784$
B. decumbens	$-0.9^{c} \pm 0.03$	$544.86^{c} \pm 15.774$	$0.87^{b} \pm 3.7$
Mean	-0.29	614.65	17.05
SEM (P<0.05)	0.135	19.759	3.184
P-value	<0.0001	0.0001	0.0053

$^{a, b, c}$ Means with different superscripts in the same column are significantly different ($p<0.05$)

Key: SI=Selectivity index, DMI=Dry matter intake, ADG=Average daily gain.

Selectivity indices were different (p<0.05) between the grasses. However, the selectivity index for *E. macrostachyus* and *C. ciliaris* grass species were not different (p>0.05). No difference (p>0.05) in dry matter intake was evident in sheep fed *E. macrostachyus* and *C. ciliaris* grass species (semi-arid grasses) either. Similarly, DMI in sheep fed *C. gayana* and *B. decumbens* (humid grasses) did not differ (p>0.05). There was however a higher (p<0.05) DMI in sheep fed semi-arid grasses than in the sheep fed humid grass. Average daily gain (ADG) of sheep fed *B. decumbens* was lower (p<0.05) than in the sheep fed on the other grasses. Both DMI and ADG were high in the grasses that were more selected by the sheep. The results also showed that as DMI increases, there was a concurrent increase in ADG.

Weekly dry matter intake (DMI) for *E. macrostachyus* and *C. ciliaris* increased consistently for the entire period of the study while dry matter intake (DMI) of *C. gayana* and *B. decumbens* declined consistence through acclimatization period to week 2 and week 5 respectively after which marginal increase was observed (figure 4.1).

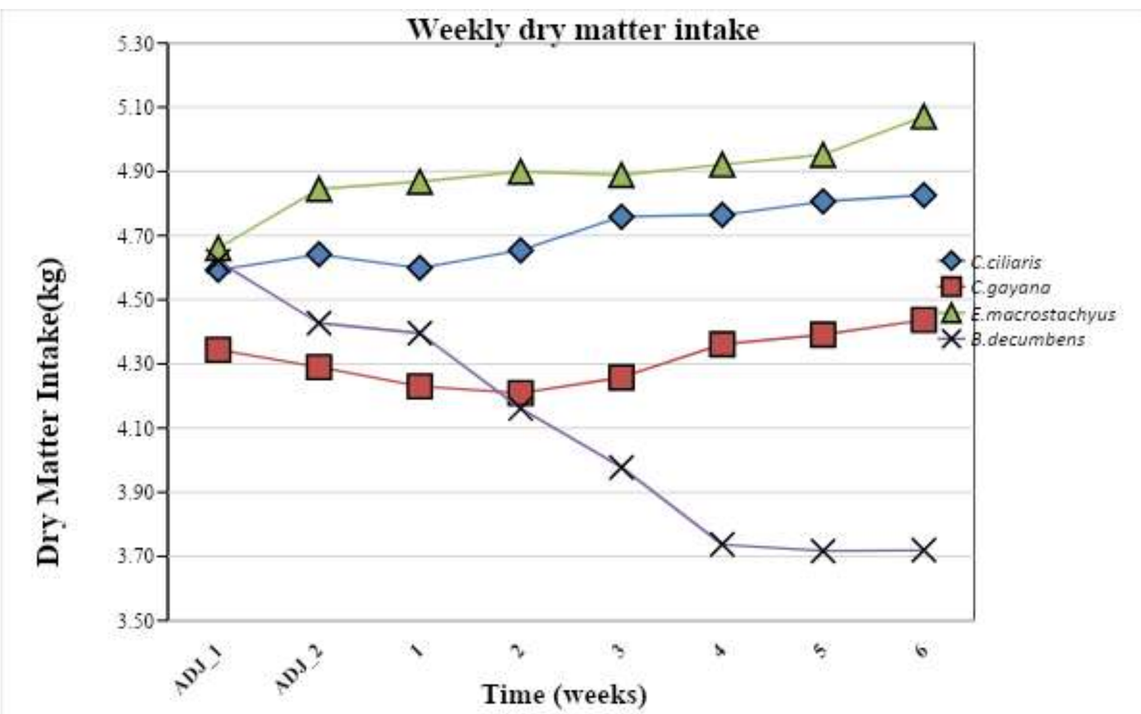

Figure 4.1: Weekly dry matter intake of different grasses by sheep

ADJ_1=Adjustment week 1, ADJ_2= Adjustment week 2.

Weekly live weight gain trend showed a consistent increase in live weight for sheep fed on *E. macrostachyus* and *C. ciliaris* for the entire period of the study with *E. macrostachyus* causing highest live weight gain. On the other hand, there was a sharp decline in live weight during acclimatization period for sheep fed on *C. gayana*. Sheep fed on Brachiaria *decumbens* recorded consistent decline in live weight up to 4 weeks after acclimatization period of 14 days beyond which marginal increase in weight was observed (figure 4.2).

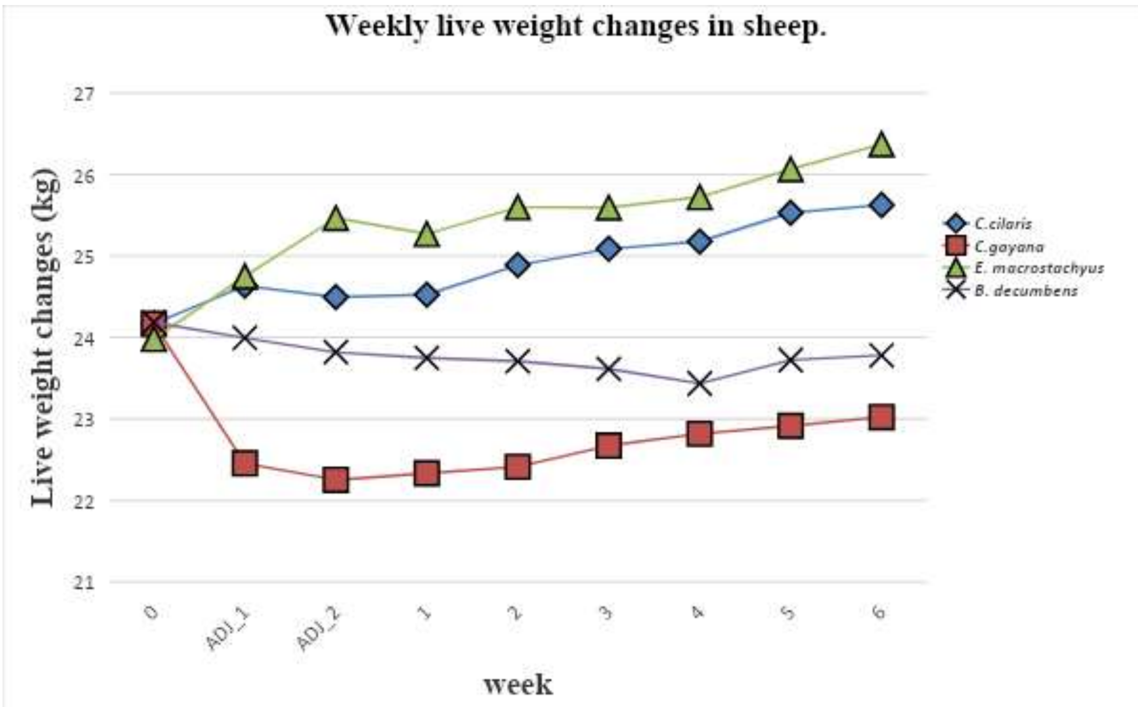

Figure 4.2: Weekly live weight changes in sheep fed different grass species
ADJ_1=Adjustment week 1, ADJ_2= Adjustment week 2,

There was higher ($p<0.05$) average daily gain (ADG), and dry matter intake (DMI) in sheep fed with humid and semi-arid grasses (Table 4.5).

Table 4.5: Mean (±SE) daily gain, mean (±SE) daily dry matter intake, mean (±SE) crude protein, mean (±SE) crude fibre and mean (±SE) digestibility for semi-arid and humid grass categories fed to sheep.

Category	**ADG (g)**	**DMI (g)**	**CP**	**CF**	**IVDMD**
Semi-arid	25.4 ± 2.71	673.6 ± 23.53	56.8 ± 0.37	473.2± 3.71	429.7 ± 6.63
Humid	9.3 ± 3.83	563.0 ± 15.28	42.2^{b}± 2.73	507± 9.3	348 ± 17.02
Mean	17.04	614.65	49.48	490.13	388.83
SEM(p<0.05)	3.18	19.76	2.55	6.994	15.08
t value	-3.25	-4.04	-5.27	3.37	-4.47
DF	13	13	5.18	10	10
P <0.05	0.0063	0.0014	0.003	0.0072	0.0012

Key: ADG=Average daily gain; DMI = Dry matter intake; IVDMD= *In vitro* dry matter digestibility; CF= crude fibre; CP=crude protein.

Dry matter intake, crude protein, digestibility and live weight gain were higher ($p<0.05$) for semi-arid grass category compared to the humid category while crude fibre was lower ($p<0.05$) in the humid category than in the semi-arid category. According to Afzal *et al.* (2007), a grass is considered to be of good nutritive value if it has a high CP level, low CF level and high digestibility. Based on this consideration, semi-arid category had better nutritive value and therefore led to a higher weight gain than the humid grass category.

4.4 Relationship between variables

Pearson correlation analysis was conducted to establish the relationship between CP and average daily gain (ADG), dry matter intake, SI and IVDMD. There was positive correlation between CP, selectivity index (SI), average daily gain (ADG), dry matter intake (DMI), and *in vitro* dry matter digestibility (IVDMD). The results also showed a negative relationship between crude fibre (CF) and all the variables. (Table 4.6).

Table 4.6: Correlation between crude fibre, crude protein, selectivity index, average daily gain, dry matter intake and *in vitro* dry matter digestibility.

Parameter	CF	CP	SI	ADG	DMI	IVDMD
CF	1	-0.37941	-0.67545	-0.25761	-0.62728	-0.99711**
CP		1	0.79234	0.99103**	0.95526*	0.44628
SI			1	0.75101	0.90681	0.72491
ADG				1	0.91293	0.32854
DMI					1	0.68386
IVDMD						1

*significance level ($p \leq 0.05$), ** significance level ($p \leq 0.01$), ***significance level $p \leq 0.001$).

Key: ADG=Average daily gain; DMI=Dry matter intake; CF=Crude fibre; CP=Crude protein; SI=Selectivity index; IVDMD=*In vitro* dry matter digestibility.

The results show that as CF content increases, the quality and digestibility of forage declines (negative correlation). Fibrous feed material discouraged selection and intake in sheep while high CP content encouraged selection and intake and hence an increase in weight gain.

CHAPTER FIVE

5.0 DISCUSSION

Enteropogon macrostachyus was the most selected grass followed by *C. ciliaris*. This may be attributed to higher palatability, higher nutritive value and digestibility compared to the other grasses. Provenza *et al.* (2003) reported that differences in secondary compounds, macronutrient concentrations, and flavors could lead to differences in preference by sheep for the different grasses and hence selectivity. Rook *et al.* (2002) noted that chemical composition of a plant and the nutritional status of the animal under consideration may affect diet selection. According to Mayulu (2016), palatability of a forage is influenced by chemical properties, that is, water content, CP, CF and other substances. This is in concurrence with the results of the current study which found that *E. macrostachyus* had the highest CP content and it was the most palatable (sheep spent more time eating it and it was the most eaten). Similarly, the *in vitro* dry matter digestibility for *E. macrostachyus* was highest among the six grass species in the study. In addition, Ziblim *et al.* (2019) found that differences in the nutritional, anti-nutritional and other factors like tastes, smell and texture of the forage might also be accountable for the differences in selectivity indices of grasses. This finding conforms to the results of the current study where selectivity index was highest in *E. macrostachyus* whose palatability and CP were highest. Crude protein content and palatability were lowest in *B. Decumbens* and so was the DMI. This also explains why the selectivity for *B. decumbens* was the least among the six grass species.

According to Kadenyi *et al.* (2019), *E. macrostachyus* is highly palatable and is commonly overgrazed due to its high preference by livestock. This explains why the grass had the highest selectivity index and the highest dry matter intake by sheep in the current study. Mayulu (2016) found out that palatability is high in forages with high nutritive value agreeing with the finding of the current study where *E. macrostachyus* and *C ciliaris* had the highest and the second highest CP content, digestibility and highest palatability, respectively compared to other grasses in the study whose CP content, palatability and digestibility were low.

Crude protein (CP) and digestible dry matter are the most important components of a feed (Afzal *et al.*, 2007). Crude protein in the current study was lower for all the grasses than the minimum of $75gKg^{-1}$ of DM necessary for optimum rumen function and production as recorded by Van Soest (1994). Mechanical loss of leaves during baling may have contributed to the low CP in the experimental grasses since leaves are rich in CP and other nutrients. Njarui *et al.* (2016) found out that when *B. decumbens* is grown in regions with high temperatures, it exhibits fast growth and accumulated more fibre leading to low CP and low digestibility. This agrees with the finding of the current study in which *B. decumbens* grown in lower eastern parts of Kenya had more fibre content resulting in low CP and hence low digestibility. The finding of the current study also agrees with De Klein *et al.* (2006) who recorded that the amount of CP in a forage determines the dietary nourishment of animals by affecting forage digestibility.

The study also showed that *C. gayana,* which is also a humid grass, was higher in quality compared to *B. decumbens* though both were grown in semi-arid conditions. This may be attributed to the wide ecological adaptation of *C. gayana*. Osman *et al*. (2014) recorded that the natural distribution of *C. gayana* grass through much of Africa demonstrates a wide environmental adaptation. The grass grows in many parts of the country but not in very dry conditions. On the contrary *C. ciliaris, E. macrostachyus*, *E. superba* and *C. roxburghiana* are range grasses adapted to high temperatures and the moisture stress experienced in semi-arid regions therefore the C.P levels in the range grasses were higher than for humid grasses. A report by Pratt and Gwynne (1977) showed that semi-arid grasses have evolved adaptive mechanisms for survival under low soil moisture levels and are preferred to exotic species because they give best results in East African rangelands.

Calcium (Ca) and phosphorus (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 $30\text{-}120gKg^{-1}$ DM reported by Linn and Martin (1999).

Fibre fractions are components of cell walls and 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 with NDF < 500gKg^{-1} of DM as high quality while those with NDF > 600gKg^{-1} of DM as poor forages. In this study, all the grasses had NDF > 600gKg^{-1} of DM meaning their quality was poor according to Van Suun (2006). This may explain the low intake and digestibility of all the grasses. ADF in a forage consists of cellulose and lignin and it relates to digestibility. Like NDF, high values of ADF in a forage depress digestibility. Nussio *et al.* (1998), noted that forage with ADF content of 400 g Kg $^{-1}$ of DM or more exhibits low intake and digestibility. In the current study, all the experimental grasses had an ADF of more than 400 g Kg $^{-1}$ of DM which also explains the low intake and digestibility of the grasses. Similarly, Mean ADL values for all the grasses ranged between 102 g Kg^{-1}DM to 163 g Kg^{-1}DM which is far above 34 g Kg^{-1} DM to 57 g Kg^{-1}DM, the range reported by Sultan *et al.* (2007) for range grasses when mature. The current study also found a negative relationship between diet selection and fibre fractions conforming to the finding by Moore and Jung (2001) who found a negative relationship between fibre fractions and forage digestibility.

De Gues (1977) reported digestibility of between 500 g Kg^{-1}DM and 650 g Kg^{-1}DM for tropical grasses ranges and digestibility of between 650 g Kg^{-1}DM and 800 g Kg^{-1}DM for temperate grasses. Digestibility of all grasses in this study ranged from 310 g Kg^{-1}DM to 443 g Kg^{-1}DM which is far below the range indicated by De Gues (1977). The finding of Rotz and Muck (1994) that increase in storage period results to increase in structural carbohydrates hence low CP and low digestibility agree with the finding of the current study where low CP, high structural carbohydrates and low digestibility of hay fed to sheep were associated with a storage period of 3 Months.

The decline in DMI for *C. gayana* and *B. decumbens* beyond the acclimatization period up to week 2 and week 4 respectively may be attributed to lack of previous experience on the grass by the sheep in addition to the low CP content and high fibre content of the grasses as found in the current study. Arnold (1970a) noted that intake of pasture in which the sheep has no previous experience on it may be depressed by 50% for as long as 10 months.

Sheep in this study were sourced from one ranch dominated with semi-arid grasses. This could explain the reason why the sheep took more time to acclimatize to humid grasses. The consistent increase in DMI for *E. macrostachyus* and *C. ciliaris* may be attributed to the high CP level, high palatability and high digestibility. This finding agrees with Lechner-Doll *et al*. (1995) who recorded that high quality food is relatively rapidly digested and passed down through the animal's digestive tract and as such stimulates more food intake and thus increases animal productivity.

Morais *et al.* (2014), reiterated that the difference in weight gain of an animal is based on the quality of the roughage if the level of supplementation is the same. In the current study, all the experimental sheep were only supplemented with minerals and therefore the major contributing factor to the differences in their weight changes was the quality of roughages, which according to Mohajer *et al.* (2013) is based on crude protein, crude fibre and digestibility. Mayulu (2016) found out that increase in average daily gain may be due to increase in body tissue formation as a result of high protein utilization which results from increase in dry matter intake, crude protein intake and high feed digestibility. This finding explains why *E. macrostachyus* and *C. ciliaris* in the current study caused the highest and the second-highest average daily gain in sheep respectively. Similarly, Mayulu (2016) found out that low magnitude of average daily gain on sheep is an indication that they had been fed on poor quality and low palatable feed. This also explains the low weight gain caused by *B. decumbens* in the sheep. The low intake of *B. decumbens* may be attributed to low palatability which may have resulted in inadequate energy and CP intake.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Diet selection and intake by sheep were higher for semi-arid grasses than for humid grasses when both semi-arid and humid grasses were grown in semi-arid conditions. This is because semi-arid grasses are adapted to survive under high temperature and low moisture conditions without deteriorating nutritive quality hence give better results than humid grasses grown under the same conditions. Ecological adaptations of a forage influence its nutritive quality which also affects the preference and selection of the forage by the sheep. Crude protein content, fibre contents and digestibility of experimental feeds influence diet choice by the sheep. The sheep selected grasses with high levels of crude protein, high digestibility and low crude fibre and rejected grass with lower crude protein, lower digestibility and high crude fibre. Nutritive quality in forages is commonly interpreted in terms of crude protein, fibre components and digestibility. A forage with high CP, low fibre components and high digestibility is considered to be of high nutritive quality. High-fibre components indicate poor quality forage with low CP and digestibility and as a result, they are either rejected or their selection is low leading to low dry matter intake. *Enteropogon macrostachyus* and *C. ciliaris* had the highest and second highest nutritive quality respectively resulting in high selection and intake. Herbivores are capable of assessing forage nutritive quality when making food choices and they choose forage of high nutritive value. Diet selection is positively correlated to DMI, crude protein and digestibility of forage and is negatively correlated to fibre components.

Diet selection influences dry matter intake and hence the performance of sheep. The selection and intake of *E. macrostachyus* and *C. ciliaris* by sheep were higher than the selection and intake of *B. decumbens* and *C. gayana.* As a result, *E. macrostachyus* and *C. ciliaris* resulted in higher average daily gain(ADG) in sheep compared to *B. decumbens* and *C. gayana*. An increase in live weight may be due to an increase in body tissue formation as a result of high protein utilization which resulted from the increase in dry matter intake, crude protein intake and high digestibility of the grass. As a result of low selection and intake of *B. decumbens* and *C. gayana*, the two grasses resulted in the lowest and second lowest average daily gain (ADG) in sheep, respectively.

6.2 Recommendations

There is a need to advise farmers on good pasture establishment and management husbandry practices to produce high-quality pasture since diet selection and intake are influenced by the nutritive quality and physical characteristics of feed. Herbivores are capable of assessing the nutritive quality of feed when making diet selections and they choose forage of high nutritive value and with favourable external plant attributes. Practices such as proper fertilization and harvesting at the right time are key in the production of good quality pasture. Using appropriate harvesting and bailing technologies that lead to minimal loss of nutrients through loss of leaves is also important in ensuring good quality pasture.

Farmers should be advised on different ecological conditions for different grasses so that they establish the right grasses where they are best suited. Different grasses are adapted to different ecological conditions and when a humid grass is grown under semi-arid conditions which it is not adapted for, the nutritive quality deteriorates and sheep may reject it leading to low dry matter intake and hence low weight gain.

There is also a need for further research on diet selection, intake and weight gain in sheep fed in a cafeteria system with humid semi-arid grasses grown in both humid and semi-arid conditions.

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APPENDICES

Appendix 1: Feeding time (seconds) data entry tool for diet selection study

GRASS (Treatment)	Day	Sheep 5 (Rep 1)	Sheep 7 (Rep 2)	Sheep 1 (Rep 3)	Sheep 2 (Rep 4)	Sheep 0 (Rep 5)
E. superba	1					
C. gayana	1					
C. ciliaris	1					
B. decumbens	1					
E. macrostachyus	1					
C. roxburghiana	1					
E. superba	2					
C. gayana	2					
C. ciliaris	2					
B. decumbens	2					
E. macrostachyus	3					
C. roxburghiana	3					
E. superba	3					
C. gayana	3					
C. ciliaris	3					
B. decumbens	3					
E. macrostachyus	3					
C. roxburghiana	3					
E. superba	4					
C. gayana	4					
C. ciliaris	4					
B. decumbens	4					
E. macrostachyus	4					
C. roxburghiana	4					
E. superba	5					
C. gayana	5					
C. ciliaris	5					
B. decumbens	5					
E. macrostachyus	5					
C. roxburghiana	5					

Appendix 2:Data collection tool on number times of feed visit.

GRASS (Treatment)	Day	Sheep 5 (Rep 1)	Sheep 7 (Rep 2)	Sheep 1 (Rep 3)	Sheep 2 (Rep 4)	Sheep 0 (Rep 5)
E. superba	1					
C. gayana	1					
C. ciliaris	1					
B. decumbens	1					
E. macrostachyus	1					
C. roxburghiana	1					
E. superba	2					
C. gayana	2					
C. ciliaris	2					
B. decumbens	2					
E. macrostachyus	3					
C. roxburghiana	3					
E. superba	3					
C. gayana	3					
C. ciliaris	3					
B. decumbens	3					
E. macrostachyus	3					
C. roxburghiana	3					
E. superba	4					
C. gayana	4					
C. ciliaris	4					
B. decumbens	4					
E. macrostachyus	4					
C. roxburghiana	4					
E. superba	5					
C. gayana	5					
C. ciliaris	5					
B. decumbens	5					
E. macrostachyus	5					
C. roxburghiana	5					

Appendix 3: Data collection tool on feed intake(g) during diet selection study

GRASS (Treatment)	Day	Weight of bucket + weight of grass offered	**Weight of Bucket + Amount of grass refused**				
			Sheep 5 (Rep 1)	Sheep 7 (Rep 2)	Sheep 1 (Rep 3)	Sheep 2 (Rep 4)	Sheep 0 (Rep 5)
E. superba	1						
C. gayana	1						
C. ciliaris	1						
B. decumbens	1						
E. macrostachyus	1						
C. roxburghiana	1						
E. superba	2						
C. gayana	2						
C. ciliaris	2						
B. decumbens	2						
E. macrostachyus	3						
C. roxburghiana	3						
E. superba	3						
C. gayana	3						
C. ciliaris	3						
B. decumbens	3						
E. macrostachyus	3						
C. roxburghiana	3						
E. superba	4						
C. gayana	4						
C. ciliaris	4						
B. decumbens	4						
E. macrostachyus	4						
C. roxburghiana	4						
E. superba	5						
C. gayana	5						
C. ciliaris	5						
B. decumbens	5						
E. macrostachyus	5						
C. roxburghiana	5						

Appendix 4: Data collection tool for feed intake(g) during intake and live weight gain study.

GRASS (Treatment)	Sheep ID (Repl.)	Weight of the weighing bucket + feed offered	Weight of bucket + refused grass						
			1	2	3	4	5	6	7
C. ciliaris	1								
C. ciliaris	2								
C. ciliaris	3								
C. ciliaris	4								
C. gayana	1								
C. gayana	2								
C. gayana	3								
C. gayana	4								
E. macrostachyus	1								
E. macrostachyus	2								
E. macrostachyus	3								
E. macrostachyus	4								
B. decumbens	1								
B. decumbens	2								
B. decumbens	3								
B. decumbens	4								

Appendix 5: Live weight register for intake and live weight gain study.

			Time in weeks								
Grass (Treatment)	Sheep ID (Reps)	Weight on delivery	Adjust Wk. 1	Adjust Wk. 2	1	2	3	4	5	6
C. ciliaris	1									
C. ciliaris	2									
C. ciliaris	3									
C. ciliaris	4									
C. gayana	1									
C. gayana	2									
C. gayana	3									
C. gayana	4									
E. macrostachyus	1									
E. macrostachyus	2									
E. macrostachyus	3									
E. macrostachyus	4									
B. decumbens	1									
B. decumbens	2									
B. decumbens	3									
B. decumbens	4									

Appendix 6: Log10 transformed data on time, intake, visits and selectivity index for Diet selection study

GC	CC	Intake	Time	Visits	SI	(SI+1)	log_ Intake	log Time	log_ Visits	log_ SI_1
ES	S	10	43.8	0.3	-0.85	0.15	1	1.64147	-0.52288	-0.82391
ES	S	103	280.2	2.5	-0.13	0.87	2.01284	2.44747	0.39794	-0.06048
ES	S	11	50.2	0.2	-0.86	0.14	1.04139	1.7007	-0.69897	-0.85387
ES	S	98	764.8	2.2	-0.24	0.76	1.99123	2.88355	0.34242	-0.11919
ES	S	56	215.6	1.7	-0.45	0.55	1.74819	2.33365	0.23045	-0.25964
CG	H	7	44.6	1.1	-0.89	0.11	0.8451	1.64933	0.04139	-0.95861
CG	H	48	34.5	0.6	-0.48	0.52	1.68124	1.53782	-0.22185	-0.284
CG	H	19	2.9	0.1	-0.76	0.24	1.27875	0.4624	-1	-0.61979
CG	H	36	155.9	1	-0.64	0.36	1.5563	2.19285	0	-0.4437
CG	H	34	69.4	0.7	-0.62	0.38	1.53148	1.84136	-0.1549	-0.42022
CC	S	58	103.3	2.5	-0.35	0.65	1.76343	2.0141	0.39794	-0.18709
CC	S	95	152.3	1.8	-0.17	0.83	1.97772	2.1827	0.25527	-0.08092
CC	S	64	110.6	1	-0.37	0.63	1.80618	2.04376	0	-0.20066
CC	S	81	300.8	2	-0.33	0.67	1.90849	2.47828	0.30103	-0.17393
CC	S	123	611.5	2.5	-0.09	0.91	2.08991	2.7864	0.39794	-0.04096
BD	H	5	13.3	0.2	-0.92	0.08	0.69897	1.12385	-0.69897	-1.09691
BD	H	3	19.8	0.4	-0.96	0.04	0.47712	1.29667	-0.39794	-1.39794
BD	H	16	1.3	0.1	-0.8	0.2	1.20412	0.11394	-1	-0.69897
BD	H	20	2.1	0.1	-0.78	0.22	1.30103	0.32222	-1	-0.65758
BD	H	10	4.3	0.4	-0.88	0.12	1	0.63347	-0.39794	-0.92082
EM	S	627	3284	4.5	0.69	1.69	2.79727	3.5164	0.65321	0.22789
EM	S	546	3041.2	3.9	0.61	1.61	2.73719	3.48304	0.59106	0.20683
EM	S	675	3416.4	2.9	0.67	1.67	2.8293	3.53357	0.4624	0.22272
EM	S	709	2271.8	3.4	0.64	1.64	2.85065	3.35637	0.53148	0.21484
EM	S	618	2607.5	3.6	0.63	1.63	2.79099	3.41622	0.5563	0.21219
CR	S	4	13.6	0.5	-0.94	0.06	0.60206	1.13354	-0.30103	-1.22185
CR	S	5	4.3	0.2	-0.93	0.07	0.69897	0.63347	-0.69897	-1.1549
CR	S	35	2.7	0.1	-0.6	0.4	1.54407	0.43136	-1	-0.39794
CR	S	10	2.4	0.3	-0.89	0.11	1	0.38021	-0.52288	-0.95861
CR	S	28	32.3	0.3	-0.68	0.32	1.44716	1.5092	-0.52288	-0.49485

Appendix 7: The ANOVA Procedure for diet selection variables

Dependent Variable: Log Intake

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	11.8344589	2.36689178	26.27	<.0001
Error	24	2.16277205	0.0901155		
Corrected Total	29	13.99723095			

R Square	Coeff var.	Root MSE	log Intake Mean
0.845486	19.03552	0.300192	1.577012

Dependent Variable: log Time

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	26.26300010	5.25260002	14.60	<.0001
Error	24	8.63404922	0.35975205		
Corrected Total	29	34.89704932			

R Square	Coeff var.	Root MSE	log time Mean
0.752585	33.96479	0.599793	1.765927

Dependent Variable: Log Visits

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	6.06673037	1.21334607	11.39	<.0001
Error	24	2.55630999	0.10651292		
Corrected Total	29	8.62304037			

R Square	Coeff var.	Root MSE	log visits Mean
0.703549	-245.9799	0.326363	-0.132679

Dependent Variable: Log (SI+1)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	4.81820411	0.96364082	12.62	<.0001
Error	24	1.83292241	0.07637177		
Corrected Total	29	6.65112652			

R Square	Coeff var.	Root MSE	log (SI+1) Mean
0.724419	61.67319	-0.276354	-0.448095

Appendix 8: The ANOVA Procedure for Chemical variables

Dependent Variable: DM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1514.615000	302.923000	11.68	0.0003
Error	12	311.320000	25.943333		
Corrected Total	17	1825.935000			

R-Square	Coeff Var	Root MSE	DM Mean
0.829501	0.531177	5.093460	958.9000

Dependent Variable: ASH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	4669.600000	933.920000	59.96	<.0001
Error	12	186.900000	15.575000		
Corrected Total	17	4856.500000			

R-Square	Coeff Var	Root MSE	ASH Mean
0.961515	4.060203	3.946517	97.20000

Dependent Variable: EE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	807.933333	161.586667	7.32	0.0023
Error	12	264.866667	22.072222		
Corrected Total	17	1072.800000			

R-Square	Coeff Var	Root MSE	EE Mean
0.753107	18.20972	4.698108	25.80000

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	901.2383333	180.2476667	158.50	<.0001
Error	12	13.6466667	1.1372222		
Corrected Total	17	914.8850000			

R-Square	Coeff Var	Root MSE	CP Mean
0.985084	2.137801	1.066406	49.88333

Dependent Variable: CF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	6400.231667	1280.046333	7.23	0.0024
Error	12	2123.733333	176.977778		
Corrected Total	17	8523.965000			

R-Square	Coeff Var	Root MSE	CF Mean
0.750851	2.693248	13.30330	493.9500

Dependent Variable: NFE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	970.653333	194.130667	1.25	0.3477
Error	12	1870.486667	155.873889		
Corrected Total	17	2841.140000			

R-Square	Coeff Var	Root MSE	NFE Mean
0.341642	3.747358	12.48495	333.1667

Dependent Variable: NDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	6637.92569	1327.58514	3.81	0.0267
Error	12	4177.60333	348.13361		
Corrected Total	17	10815.52903			

R-Square	Coeff Var	Root MSE	NDF Mean
0.613740	2.529477	18.65834	737.6361

Dependent Variable: ADF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	11819.91444	2363.98289	46.94	<.0001
Error	12	604.33000	50.36083		
Corrected Total	17	12424.24444			

R-Square	Coeff Var	Root MSE	ADF Mean
0.951359	1.470649	7.096537	482.5444

Dependent Variable: ADL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	9375.860694	1875.172139	40.43	<.0001
Error	12	556.533333	46.377778		
Corrected Total	17	9932.394028			

R-Square	Coeff Var	Root MSE	ADL Mean
0.943968	5.183290	6.810123	131.3861

Dependent Variable: *IN VITRO*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	43055.82111	8611.16422	109.90	<.0001
Error	12	940.26833	78.35569		
Corrected Total	17	43996.08944			

R-Square	Coeff Var	Root MSE	*IN VITRO* Mean
0.978628	2.324581	8.851875	380.7944

Dependent Variable: Ca

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1.40458333	0.28091667	3.06	0.0522
Error	12	1.10166667	0.09180556		
Corrected Total	17	2.50625000			

R-Square	Coeff Var	Root MSE	Ca Mean
0.560432	14.25856	0.302994	2.125000

Dependent Variable: P

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.98902778	0.19780556	3.32	0.0411
Error	12	0.71500000	0.05958333		
Corrected Total	17	1.70402778			

R-Square	Coeff Var	Root MSE	P Mean
0.580406	19.31317	0.244097	1.263889

Appendix 9: The GLM Procedure for intake live weight

Dependent Variable: TDMI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	127.0805466	31.7701367	18.11	0.0001
Error	10	17.5451790	1.7545179		
Corrected Total	14	144.6257256			

R-Square	Coeff Var	Root MSE	TDMI Mean
0.878686	5.130977	1.324582	25.81540

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GC	3	64.82443536	21.60814512	12.32	0.0011
IW	1	38.96171654	38.96171654	22.21	0.0008

Dependent Variable: DDMI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	72041.28318	18010.32080	18.11	0.0001
Error	10	9947.39957	994.73996		
Corrected Total	14	81988.68275			

R-Square	Coeff Var	Root MSE	DDMI Mean
0.878674	5.131267	31.53950	614.6533

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GC	3	36751.26537	12250.42179	12.32	0.0011
IW	1	22084.28209	22084.28209	22.20	0.0008

Dependent Variable: TWG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	2788814.949	697203.737	7.22	0.0053
Error	10	965545.051	96554.505		
Corrected Total	14	3754360.000			

R-Square	Coeff Var	Root MSE	TWG Mean
0.742820	43.39835	310.7322	716.0000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GC	3	2700432.584	900144.195	9.32	0.0030
IW	1	16096.615	16096.615	0.17	0.6917

Dependent Variable: ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1580.944483	395.236121	7.22	0.0053
Error	10	547.372475	54.737248		
Corrected Total	14	2128.316958			

R-Square	Coeff Var	Root MSE	ADWG Mean
0.742814	43.39919	7.398463	17.04747

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GC	3	1530.838651	510.279550	9.32	0.0030
IW	1	9.126598	9.126598	0.17	0.691

Appendix 10: Pearson Correlation between crude fibre, crude protein, selectivity index, average daily weight gain, dry matter intake, selectivity index, and in vitro dry matter digestibility

VARIABLE	CF	CP	SI	ADG	DDMI	INDMD
CF	1	-0.37941	-0.67545	-0.25761	-0.62728	-0.99711
		p=0.6206	p=0.3246	p=0.7424	p=0.3727	p=0.0029
CP		1	0.79234	0.99103	0.95526	0.44628
			p=0.2077	p=0.009	p=0.0447	p=0.5537
SI			1	0.75101	0.90681	0.72491
				p=0.249	p=0.0932	p=0.2751
ADG				1	0.91293	0.32854
					p=0.0871	p=0.6715
DDMI					1	0.68386
						p=0.3161
INVDMD						1