EVALUATION OF THE NUTRITIVE VALUE OF SELECTED INDIGENOUS TREE BROWSES AS FEED FOR RUMINANT LIVESTOCK IN SOUTH SUDAN

JOHN LORO IGA MANGARA

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DECLARATION AND RECOMMENDATION

DECLARATION

I hereby declare that this thesis is entirely my original work with the exception of such references and quotations that have been attributed to their authors or sources. This thesis has never been submitted for any degree of examination here in Egerton or in any other university.

Signature……………………………. Date…………………………..

John Loro Iga Mangara

KD11/0453/14

RECOMMENDATION

This thesis has been submitted for examination with our approval as University Supervisors

Signature…………………………………… Date………………………..

PROF. A.Y. Guliye, PhD

Associate Professor,

Egerton University, Department of Animal Science

Signature………………………………….. Date…………………………

Dr. P. K. Migwi, PhD

Senior Lecturer,

Egerton University, Department of Animal Science

Signature…………………………………. Date…………………………..

Dr. J. O. Ondiek, PhD

Senior Lecturer,

Egerton University, Department of Animal Science

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DEDICATION

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ABSTRACT

In South Sudan livestock is an important source of livelihood however, animal productivity is very low due to lack of adequate feed particularly in dry season. In this study five objectives were carried out. In objective 1, a questionnaire survey was conducted amongst livestock keepers and generally 25 most commonly browsed species were identified. The study indicate that, there is a wide range and diversity of browse species that could serve as important livestock feed. The study evaluated 5 species as feed for ruminant livestock and these include; *Acacia nilotica (An), Balanites aegyptiaca (Ba), Combretum adenogonium (Ca), Sclerocarya birrea (Sb) and Ziziphus spina-christi (Zs).* Objective 2 assessed the nutritive value of selected indigenous browses. *Combretum adenogonium* and *Zs* had the highest CP values. The browse species had phenolic and tannin contents higher than 50 g/kg DM, the maximum tolerable limit in ruminant nutrition, except for *Ba* and *Zs*, which had significantly ($P < 0.05$) lower total extractable phenols (TEP). The contents of macro and micro elements differed significantly ($P < 0.05$) among the browse species. The means (objective 3) for *in vitro* gas production ranged from 30.6 to 45 ml/kg DM for 3 and 96 hr, respectively. *Balanites aegyptiaca, Ca* and *Zs* at 96hr had high gas production potential compared to *An* and *Sb*. *In vitro* OM degradability (OMD) was significantly ($P < 0.05$) different between the browses. *Combretum adenogonium* and *Z. spina-christi* had the highest OMD but not significantly ($P > 0.05$) different to *Ba*, while *An* and *Sb* had lower but similar ($P > 0.05$) OMD values. The highly degradable browses had similar ME values but significantly ($P < 0.05$) higher compared to *An* and *Sb*. In objective 4, *Ca* and *Zs* were fed to 20 cross-bred goats singly and in combination as supplement to a basal diet of Rhodes grass (*Chloris gayana*) hay. Four goats were allocated randomly to each of the five dietary treatments in a completely randomized design. The dietary ratios were as follows; C0Z100 (D1), C25Z75 (D2), C50Z50 (D3), C75Z25 (D4) and C100Z0 (D5). The dry matter intake (DMI) was significantly ($P < 0.05$) different in all the dietary treatments. Basal diet intake was significantly ($P < 0.05$) high in D5. Higher intake of supplement was observed at high inclusion rate of *Zs*. Total DMI increased with high inclusion rate of *Zs.* D1 had significantly high nutrient digestibility. D2 had significantly ($P < 0.05$) higher retention of nitrogen whereas D4 had least retained nitrogen. Live weight gain (g/day) was highest ($P < 0.05$) in D1 and lowest ($P < 0.05$) in D5. In objective 5, sixteen cross-bred goats were assigned randomly to four dietary treatments four goats per treatment in a complete randomized design. The goats were fed graded levels of *Zs* as follows; 0 (T1), 20 (T2), 30 (T3) and 40% (T4). DMI and digestibility was ($P < 0.05$) high in supplemented diets. More nitrogen was retained in the supplemented treatments, while weight gain was negative in T1 (control). It is concluded that the indigenous forages can provide adequate sources of nutrients to ruminant livestock. The browse fodders play an important role as feed, contributing significant feed resources for livestock particularly as dry season feed when grasses and other quality forages become scare.

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ABBREVIATIONS AND ACRONYMS

ACIAR	Australian Centre of International Agricultural Research
ADG	Average Daily Gain
ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
ANOVA	Analysis of Variance
AOAC	Association of Official Methods for Analytical Chemistry
ARC	Agricultural Research Council
BHEARD	Borlaug High Education for Agriculture Research and Development
BHP	Black Head Persian Sheep
$BW^{0.75}$	Metabolic Body Weight
CES	Central Equatoria State
CP	Crude Protein
CF	Crude Fibre
CGIAR	Consultative Group of International Agricultural Research
CRD	Complete Randomized Design
DMD	Dry Matter Digestibility
DMI	Dry Matter Intake
DM	Dry Matter
DMRT	Duncan's New Multiple Range Test
DRC	Democratic Republic of Congo
EE	Ether Extract
EUEMS	Egerton University Engineering Metrological Station
ILCA	International Livestock Centre for Africa
IVOMD	*In Vitro* Organic Matter Digestibility
KALRO	Kenya Agricultural and Livestock Research Organization
ME	Metabolizable Energy
MSU	Michigan State University
MJ	Mega Joules
NDF	Neutral Detergent Fibre

NRC	National Research Council
RSS	Republic of South Sudan
SAS	Statistical Analysis Systems
SPSS	Statistical Package for Social Sciences
TAP	Tatton Agriculture Park
USAID	United States Agency for International Development

CHAPTER ONE
INTRODUCTION

1.1 Background information

South Sudan is the newest nation in Africa, with an area of 640,000 km^2 and a population of 8.2 million people (Sudan National census, 2008). Livestock is an important source of livelihood for many households in South Sudan. Ruminant livestock population is estimated at 12 million cattle, 20 million sheep and 25 million goats (Aluma, 2013). The majority of livestock is raised within tribal areas and often carry the name of the tribe in that area (Mundari cattle, Dinka cattle, Nuer cattle, Toposa Sheep). These livestock are adapted to harsh environmental conditions and often move for long distances in search of pasture and water (Thomas *et al.,* 2000). Livestock production contributes significantly to food security through direct production of food (animal products) as well as through non-food functions (Sanon, 1999). South Sudan being a landlocked country, has more of its population generally involved in agricultural production of both livestock and crops.

A well-developed livestock sector could easily constitute the second most important natural resources after oil. The country's policy and strategic plan for 2014/2015 makes livestock production of national importance in providing food and income. However, in spite of its social and economic importance, the livestock sector remains undeveloped due to various climatic, socio-economic and political constraints such as unpredictable weather characterized by drought, cultural cattle raiding, civil wars and narrow political decisions which focus mostly on oil production.

Trees and shrubs have been used for generations as multipurpose feed resources in many parts of the world (Smith, 1992). Tree leaves are an important component of the diets of goats and sheep (Holechek, 1984; and Papachristou and Nastis, 1996) and therefore play an important role in the nutrition of grazing animals in areas where other alternatives are not available (Meuret *et al.,* 1990). Generally, natural pastures constitute about 95% of livestock feed resources in the country followed by a minimal use of crop residues which account for less than 5%, while cultivated fodder crop and preserved forage are none-existent. South Sudan faces the critical problem of periodic feed shortage especially, during the dry season. Other challenges hindering livestock productivity include degeneration of natural pastures, human and livestock competition for available resources, and variability and fluctuation of rainfall (Sanon, 2007). However, a major challenge hindering realization of the full potential of this sector is the availability of good quality feeds all-year-round. This challenge is exacerbated by climate change effects occasioned by global warming. The shortage of natural pastures especially during dry periods, is of great concern necessitating the use of browse forages, which are currently underutilized. Browse forage (trees and shrubs) due to their diversity, duration of production and the availability of feed components (fresh and dry leaves; flowers and fruits) represent a critical feed resource for ruminant livestock particularly, during the dry season (Sanon, 2007). Regeneration of tree browses depend less on rainfall compared to herbaceous plants that are severely affected by rainfall. In spite of tree browse representing a vital feed resource, its potential has not been fully exploited due to lack of information about their nutritional values. The diversity and distribution of browse trees in South Sudan presents an opportunity for research as alternative or supplementary livestock feeds. Sanon (2007) stated that the ability of livestock to properly utilize available browse forages could rapidly increase food production (livestock products) and cash income for the poor people hence contributing to poverty alleviation. Therefore, this thesis is an endeavour to identify and evaluate most commonly used tree browses as ruminant feed in the Republic of South Sudan.

1.2 Statement of the problem

In South Sudan livestock and their production is one of the important food sources. South Sudan is estimated to have a livestock population of about 57 million mainly made up of cattle, sheep and goats. This population is expected to increase annually and natural pastures are rapidly getting overutilised. Livestock productivity remain low mainly due to inadequate availability of quality feed all year round. This is in spite of South Sudan potentially having enough feed resources in form of browses (trees and shrubs) to sustain a larger population of livestock. However, these feed resources have not been fully exploited due to lack of technical knowledge. Many trees and shrubs that could have a significant effect on animal production remain unused, undeveloped or poorly utilized due to lack of adequate information and understanding of their nutrient composition thus contributing to underutilization of such browses as feed resources.

1.3 Objectives

1.3.1 General objective

The study will contribute to increased availability of supplementary feeds for ruminants in dry season that improves livestock production and contribute to food security and enhanced livelihood.

1.3.2 Specific objectives

1. To identify predominant and most preferred indigenous tree browses as feed for ruminant livestock in South Sudan.
2. To determine proximate chemical composition, fibre, mineral and the anti-nutritive (phenolic compounds) composition of selected indigenous tree browses.
3. To determine the *in vitro* digestibility of selected indigenous tree browses.
4. To evaluate the effect of supplementary feeding of tree browse combination on the performance of cross-bred goats fed a basal diet of Rhodes grass hay (*Chloris gayana*).
5. To determine the effects of feeding graded levels of tree browse forage on the growth performance of cross-bred goats given a basal diet of Rhodes grass hay (*Chloris gayana*).

1.4 Hypotheses

1. Indigenous tree browses do not provide supplementary feeding for livestock in dry season.
2. There is no significant difference in proximate chemical composition, fibre, mineral and the anti-nutritive (phenolic Compounds) components of selected indigenous tree browses.
3. There is no significant difference in degradability of selected indigenous tree browses.
4. There is no significant difference on the performance of growing cross-bred goats fed browse mixture as supplement to basal diet of Rhodes grass hay.
5. There is no significant difference on feeding graded levels of browse forage on the performance of growing cross-bred goats given a basal diet of Rhodes grass hay.

1.5 Justification

In tropical Africa, the utilization of trees and shrubs as livestock feed is progressively becoming important particularly where protein sources are unavailable or expensive. In South Sudan, there is inadequate information on the nutritive value of indigenous browse forages and their use as supplementary feed for livestock. Understanding the nutritive content of indigenous forages and the performance of livestock fed on them could contribute to household feed security of livestock producers who may not afford to purchase commercial protein supplements. Additionally, the utilization of these browses may enhance availability of livestock feed throughout the year thus increasing livestock productivity thereby contributing to national food security.

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CHAPTER TWO
LITERATURE REVIEW

2.1 Feed resources for ruminants in South Sudan

2.1.1 Natural pastures and browses

Rangelands are generally areas unsuitable for growing crops due to low and unsteady precipitation, rough topography, fragile soils and poor drainage, but are a source of forage for livestock as well as forest products such as wood and wild foods (Abate, 2006). They consist of natural trees, shrubs, grassland and bush. Rangelands provide open space with natural features used for many recreational activities such as game viewing and hunting. The vegetation of South Sudan rangelands is savannah grassland with perennial grass species and acacia trees dominating in the low rainfall areas and woodlands in areas with higher rainfall. These savannahs provide animals with good grazing or ‵*toich*' during dry season. Both savannas and ‵*toich*' are important in their contribution to the livelihoods of the local inhabitants and the potential significance of livestock in the economy of South Sudan. Besides large number of cattle, the rangeland areas also support cultivation of different drought tolerant crops (Abate, 2006).

Rangeland production in South Sudan is mainly seasonal, with rainy season beginning from April to November. The majority of the herbaceous plants are annual, where composition and growth rate is strongly affected by the pattern and amount of rainfall (Table 1). Most of the trees and shrubs are deciduous but have longer leaf production cycles than the herbaceous plants. The availability of the pasture resources is characterized by a peak in herbaceous production in the rainy season, which decreases gradually in quantity as well as in quality until the beginning of the next rainy season though, nutritionally it meets the maintenance requirement of animals. The woody fodders are diversified, have various fodder components (leaves both green and dry, pods and flowers) and have a longer period of availability. The rivers and the large swampy areas are exploitable after the water level decreases and have high productivity during the dry season thus sustaining livestock grazing.

Table 1. Some indigenous browse species of South Sudan.

1. Acacia albida	16. *Gardenia lutea*
2. Albizia amara	17. *Hymenocardia acida*
3. *Afzelia africana*	*18. Kigelia Africana*
4. *Anogeissus leiocarpus*	*19. Khaya senegalensis*
5. *Acacia nilotica*	*20. Leptadenia lancifolia*
6. *Acacia polyacantha*	*21. Lablab purpureus spp*
7. *Annona senegalensis*	*22. Ptercarpus lucens*
8. *Balanites aegyptiaca*	*23. Piliostigma thonningii*
9. *Burkea africana*	*24. Scerocarya birrea*
10. *Combretum glutinosum*	*25. Strychnos spinosa*
11. *Detarium microcarpum*	*26. Terminalia brownie*
12. *Marsdenia abyssinica*	*27. Tamarindus indica*
13. *Entada africana*	*28. Vitex doniana*
14. *Ficus spp.*	*29. Ximenia Americana*
15. *Grewia mollis*	*30. Ziziphus spina christ*

Source: (Gaiballa and Lee, 2012).

2.1.2 Crop residues

Crop residues are the plant materials that remain after food crops have been harvested (De Leeuw, 1988). The main crops grown in South Sudan are millet, sorghum, maize, cowpea, groundnuts, broad beans and some tubers. Maize, sorghum, cassava and groundnuts are the main staple crops in the country. As more land is being cultivated to meet the needs of the growing population, crop residues have increased and become an important source of livestock feed. However, their availability depends on the size of crop land and the yield of the plant parts. All the crop residues are grazed by livestock in the field, however, there is competition in the utilization of cereal straws and stovers, since they are also used for fuel, building materials, and as mulch to protect the soil against erosion or as sources of organic matter. Crop residues are generally low in crude protein and high in fiber and therefore, considered to be of low nutritive value unless they are supplemented with key nutrients such as nitrogen and sulphur.

2.2 Importance of browse trees and shrubs

Browse refers to leaves and twigs from shrubs and trees available to ruminants as feed and in a broader sense also includes flowers and pods. Le Houerou (1980) explained that, the notion of browse is a complex issue, depending on plant species, animal species, forage availability, accessibility and the nutritional state of the animals. Wicken (1980) estimated that the flora of tropical Africa contains more than 7000 species of trees or shrubs, of which at least 75% are livestock browses to a greater or lesser extent, and probably about 50%, are useful to man as well. Besides, being browsed, woody plants play an important role in human lives in Sub-Saharan Africa due to their multiple uses. Species such as *Acacia albida* are valuable because of the ability to improve soil fertility through nitrogen fixation, produces green leaves in the dry season for feeding animals that in turn spread manure in the field. During the rainy season the species lose their leaves, resulting in no shading effects on crops.

Akpo *et al.* (2003) mentioned that some species in croplands have other socio-economic importance, including edible leaves or fruits, ethno-medicinal use or shade, and reduce evapotranspiration from the fields. Generally, the multiple uses of woody plants include soil maintenance and protection against erosion and dune stabilization (as windbreaks), source of energy (fire wood), construction material and with their shade reduced water loss from the soil and lower temperature. The trees serve as source of income through the sale of leaves, fruits and wood, and also have other ethno-medicinal and veterinary uses. They are also shown to influence the herbaceous cover in the Sahel, by improving flora diversity and mineral content (Akpo *et al.,* 2003).

2.3 Nutritive value of browse forages

The composition in terms of organic matter (OM), crude protein (CP), fibre and lignin contents were shown to be highly variable among browse species (Table 2 and 3). Osuga *et al.* (2006) reported OM of 822.8 g/kg DM (*Maerua angolensis*) and 936.0 g/kg DM (*Tamarindus indica*). The CP content (g/kg DM) ranges from 98.4 to 302.3 of *Olea europa* and *Calliandra calothyrsus* respectively. While, *Boscia angustifolia* has high neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents, and *Maerua angolensis* has low NDF and ADF contents. The acid detergent lignin (ADL) content has been reported to vary from 48.6 in *Terminalia brownii* to 138.3 g/kg DM in *Persia Americana* (Osuga *et al.,* 2006). The importance of browse forages as nitrogen sources for ruminants, especially during dry season, is the main contribution of the browses in different parts of the tropics where other nitrogen sources may not be readily available or are expensive *(*Osuga *et al.,* 2006). Many species of browse forages were reported to have high CP content of more than 100 g/kg DM which is above the minimum required level for ideal microbial rumen activity (Osuga *et al.,* 2006). Annison and Bryden (1998) explained that the high CP content 80 g/kg DM, justifies the use of the browse species in small quantities to supplement poor quality pastures and crop residues. Browse forages contain low to moderate content of fibre, which is a positive attribute since the voluntary DM intake and DM digestibility were dependent on the cell wall constituents (fibre) especially, the NDF and lignin (Bakshi and Wadhwa, 2004). In addition, the fibre of browse forages has been shown to be more digestible than that of grasses and crop residues possibly due to low level of lignification and high level of complementary nitrogen supply (El Hassan *et al.,* 2000).

According to Singh *et al.* (2005), the variation in different chemical compositions of browse forages may be due to several factors such as soil, species, stage of maturity and harvesting time. Yusuf (2011) reported a lower CP value (8.5%) of Mango leaf while values of 10.1 %, 20.34% and 10.5% CP were reported by Mecha and Adegbola (1980), Ajayi *et al.* (2005) and Modupe *et al.* (2009), respectively for Mango leaf. Teferedegne (2000) anticipated that environmental differences and soil characteristics influenced the chemical composition and digestibility of forages found in different parts and harvested at the same age of maturity. Similarly, may be due to a variation in relation to stage of growth of the plants and type (i.e. twigs leaves or soft stem) of foliage sampled, site of sampling (Makkar and Becker, 1998) and proportion of foliage materials sampled (Ben Salem, 2002). According to Norton (2003), feed containing less than 8% CP cannot provide the minimum ammonia levels required by rumen microorganisms to support optimum activity. Thus, mango leaves are beneficial and therefore can be used for supplementing the low protein pastures and crop residues, especially during the dry season. The levels of crude protein increased linearly with increasing level of Mango Leaf. In contrast, the levels of crude fiber decreased with increasing levels of Mango Leaf in the diets (Yusuf, 2011).

Table 2. Chemical composition (g/kg DM) of 15 indigenous Kenyan leaf browse.

Forage species	DM	OM	CP	NDF	ADF	ADL	TEPH	TET
Acacia tortilis	890.0	924.0	117.0	443.0	335.0	137.0	7.7	6.0
Maerua angolensis	876.0	941.0	321.0	449.0	332.0	969.0	11.4	0.3
Acacia nilotica	899.0	935.0	121.0	290.0	212.0	108.0	26.4	24.4
Acacia mellifera	879.0	837.0	183.0	392.0	306.0	118.0	4.9	3.6
Acacia brevispica	891.0	927.0	187.0	460.0	329.0	174.0	5.4	1.8
Acacia senegal	884.0	904.0	249.0	423.0	266.0	125.0	4.3	2.5
Zizyphus mucronata	859.0	929.0	200.0	393.0	222.0	88.2	7.2	4.1
Grewia bicolor	894.0	919.0	196.0	528.0	362.0	143.0	9.4	8.2
Acacia elatior	889.0	879.0	162.0	503.0	355.0	175.0	5.7	4.6
Balanites aegyptiaca	867.0	867.0	137.0	349.0	266.0	154.0	1.5	0.3
Acacia abyssinica	890.0	937.0	165.0	531.0	462.0	286.0	5.9	4.4
Bridelia micrantha	903.0	940.0	112.0	481.0	421.0	212.0	9.4	4.8
Albizia.amara	898.0	953.0	167.0	601.0	413.0	250.0	8.3	4.4
Albizia coriaria	874.0	935.0	169.0	482.0	373.0	156.0	1.9	0.3
Acacia hockii	888.0	952.0	121.0	218.0	160.0	53.1	26.7	24.3
SEM	3.2	8.6	14.3	25.3	21.6	56.4	2.0	2.0

Source: Ondiek *et al.* (2010).

Ondiek *et al.* (2010) demonstrated that the relatively high CP range (112 to 321 g/kg DM) of *Acacia abyssinica, Acacia brevispica, Acacia mellifera, Acacia senegal, Albizia coriaria, Albizia amara, Grewia bicolor, Zizyphus mucronata* and *Maerua angolensis* browses show the potential contribution as protein feed resources for ruminants, especially browsing goats (Table 2). Elseed *et al.* (2002) working on Sudanese browses reported variations between the early and late dry season with some nutrients (OM, NDF, ADF) being higher in the late dry season whereas CP, minerals, and digestibility of OM, Nitrogen, *In-vitro* OMD and estimated energy displayed higher values in the early dry periods. Ondiek *et al.* (2010) found *Acacia tortilis*, *Acacia mellifera, Balanites aegyptiaca* and *Zizyphus spina-christi* to be potentially valuable for dry season feeding and as protein and energy supplements. This increase in CP content has also been reported by Abdulrazak *et al.* (1997), Ben Salem *et al.* (1997), Abdulrazak *et al.* (2000), Ondiek *et al.* (2000), Abdulrazak *et al.* (2001) and Nantoume *et al.* (2001) in other tree legume browse. In spite of the high CP content, the utilization of some of these browse is hampered by various anti-nutritive factors such as phenolic compounds and condensed tannins. For example, high levels of total extractable condensed tannins (100-480 mg/kg DM) and total extractable phenolics (104-512 mg/kg DM) for *Acacia tortilis, Acacia seyal* and *Acacia nilotica* have been reported in the arid and semi-arid areas of Kenya as livestock browse (Ondiek *et al.,* 2010). Ondiek *et al.* (2010) who also found both *Maerua angolensis* and *Balanites aegyptiaca* to be low in total extractable tannins 3 and 3 g/kg DM; and 114 and 152 g/kg DM in total extractable phenolics, respectively. The author reported high TEPH and TET in *Acacia nilotica* and *Acacia hockii* as 264, 267 g/kg DM and 244, 243 g/kg DM, respectively (Table 2). The forages varied widely in the phenolics composition. The TEPH ranged from 10.0 for *Maerua angolensis* to 165.8 mg/g DM for *Terminalia brownii*. The highest TET content was found in *Terminalia brownii* (125.7 mg/g DM) and *Calliandra calothyrsus* (122.9 mg/g DM) while the lowest TET content was in *Boscia angustifolia* (1.5 mg/g DM). *Tamarindus indica* had the highest TCT (18.05 mg/g DM) while the chemical assay did not detect TCT in *Balanites aegyptiaca* and *Boscia angustifolia* (Osuga *et al.,* 2006).

Browses are also known to contain significant content of key minerals while being deficient in others. Sawe *et al.* (1998) reported that the ash levels in acacia leaves of between 5 and 10% indicated that mineral contents in the forages are either deficient or moderately adequate. Fujihara *et al.* (1992) found that the forages had on average of 24 µg/kg DM of Se, while the Cu and Zn levels ranged between 7.6 - 24.3 and 11.4 - 50.6 mg/kg DM, respectively. While Se was lower than the requirements (200 µg/kg DM) for ruminants, the Cu and Zn were adequate for sheep rather than goats, indicating that goats need a higher level of these elements. Serra *et al.* (1995) reported macro and micro-elements in diets selected by sheep as follows (%); Ca (0.51), K (0.93), Mg (0.19), Na (0.44) and P (0.27) and micro minerals (mg/kg^{-1}DM): Cu (13.5), Fe (510.9), Mn (43.8), and Zn (29.5). However, Ondiek *et al.* (2010) reported variable values especially with Ca, P, Mg, Cu, Fe and Mn which were generally lower. The mineral content of the tree browses varies from moderate to high (Abdulrazak *et al.,* 2000). Ondiek *et al.* (2010) explained that, although the Ca and P showed variation, the acacia species reported generally were rich in the micro-elements such as Mn, Mo, Zn, Co, Cu, Fe and Se showing that animals may consume adequate amounts and may only require specific supplementation (Table 5). This means that the major minerals except sodium, were within the range of values previously reported (McDowell, 1985) and are therefore adequate to address the requirements for growth. They reported that, the micro-element content is consistent with other reports (Norton, 1994; Ramirez and Ledezma-Torres, 1997; Sawe *et al.,* 1998; Khanal and Subba, 2001). Most studies demonstrated low Na content (Sawe *et al.,* 1998 and Abdulrazak *et al.,* 2000) as described in Table 2.5 by Ondiek *et al.* (2010).

Table 3. Chemical composition (g/kg DM) and metabolizable energy (ME) value (MJ/kg DM) of grass and browse species native to South Sudan rangelands

Species	CP	CF	Ca	P	ME
Cenchrus ciliaris	56.1	488.0	3.8	1.5	8.3
Panicum maximum	97.2	433.5	4.1	1.7	9.4
Pennisetum purpureum	77.9	334.8	4.0	2.1	7.7
Chloris gayana	81.3	456.1	3.9	1.9	8.5
Sorghum arundinaceum	67.3	504.5	4.9	2.9	8.3
Hyparrhenia rufa	42.0	376.5	2.6	1.5	9.0
Acacia albida fruit	109.0	202.5	-	-	11.8
Acacia tortilis leaves	128.4	105.0	38.5	2.2	11.9
Balanites aegyptiaca leaves	116.5	164.0	4.8	0.5	11.2
Leucaena leucocephala leaves	218.6	200.5	5.6	3.2	11.5

Source: (Elis, 1982).

Table 4. Chemical composition of some selected browses from South Sudan (in dry season)

Species	DM%	CP%	CF%	EE%	Ash%
Balanites aegyptiaca	97.5	8.4	45.5	1.6	6.3
Marsdenia abyssinica	96.2	15.2	31.0	3.6	9.9
Grewia mollis	95.4	2.1	38.5	2.0	8.3
Leptadenia lancifolia	93.2	5.7	24.0	3.2	6.5
Lablab purpureus	94.8	12.9	42.5	2.0	7.9
Strychnos spinosa	95.7	3.6	62.0	2.4	4.6

Source: (Gaiballa and Lee, 2012).

Table 5. Major and trace elements in 15 indigenous Kenyan browses

	Major elements, g/kg DM					Trace elements, mg/kg DM						
Species	**Ca**	**P**	**Mg**	**Na**	**S**	**Fe**	**Mn**	**Cu**	**Mo**	**Co**	**Zn**	**Se**
Maerua angolensis	12.1	2.4	4.2	0.5	2.1	116	21.5	41.8	25.8	2.5	17.2	19.5
Acacia brevispica	7.0	0.8	2.4	0.4	1.5	130	33.5	64.9	40.2	4.4	22.2	38.9
Acacia mellifera	18.6	1.3	8.7	0.6	1.5	224	22.1	31.4	30.9	3.6	15.9	47.8
Acacia tortilis	28.1	1.5	3.8	0.6	1.7	229	29.9	38.7	13.9	3.7	12.2	124
Acacia hockii	22.4	1.4	0.4	0.6	2.0	122	21.9	15.4	21.7	5.2	15.5	62.4
Zizyphus mucronata	17.4	2.6	8.5	0.6	1.7	74.8	38.5	14.4	16.6	2.9	55.7	47.3
Grewia bicolor	12.2	3.2	0.6	0.7	1.3	51.3	19.9	22.1	29.5	1.7	42.3	38.3
Acacia elatior	13.3	2.5	1.6	0.7	1.1	88.9	27.9	28.3	19.3	2.0	93.2	63.7
Acacia nilotica	12.1	1.5	1.8	0.5	2.0	200	32.3	74.9	41.9	4.6	22.8	87.9
Balanites aegyptiaca	24.4	1.6	6.3	0.5	1.8	123	22.5	33.7	19.3	2.3	32.5	48.2
Acacia Senegal	15.6	1.7	2.2	0.6	2.4	267	27.6	4.8	43.4	5.2	22.1	113
Acacia abyssinica	6.5	1.3	3.4	0.5	1.5	129	18.3	6.8	22.5	2.9	18.9	53.4
Bridelia micrantha	7.2	1.0	2.2	0.3	2.2	106	13.8	13.1	31.2	3.3	13.5	38.4
Albizia amara	8.0	1.5	3.6	0.5	2.3	123	15.2	19.1	27.2	17.4	20.3	65.1
Albizia coriaria	9.1	2.2	3.8	0.4	1.5	89.3	13.2	22.6	26.3	2.1	19.4	39.4
SEM	1.6	0.2	0.6	0.0	0.1	16.2	1.9	5.2	2.3	1.0	5.5	7.5

Source: (Ondiek *et al.,* 2010).

2.4 Voluntary feed Intake

Voluntary intake is central to ensuring effective and maximum utilization of the feed resources. Voluntary feed intake (VFI) is the single most important factor affecting production in animals and is also associated with digestibility of the feed and proportion of the digested material that's absorbed. This is reflected in the equation; VFI= D x E where, VFI= voluntary feed intake, D = Digestibility of the feed eaten and E= Efficiency of extraction of nutrients in that feed during digestion. Maximum VFI and ensuring the supply of balanced nutrients (energy, proteins and minerals) in the diet greatly determines productivity in terms of meat, milk or fibre. It represents the first pre-requisite in feeding systems which can make available fodder and supplementary nutrients that are appropriate to different types of production. The productivity of ruminants is thus linked to the potential of a feed to supply quantities and balance of nutrients for production. Yusuf (2011) reported feed intake of West African Dwarf buck (WAD). The highest average daily feed intake was obtained in the maximum inclusion of the supplement while, the least was recorded in minimum inclusion. The intake of dry matter, Organic matter, crude protein, Ether extract and Nitrogen free extract were marginally improved by inclusion of mango leaf in the diet. This improvement in nutrients intake due to inclusion of browse has also been reported when leucaena was fed to goats (Ademosun *et al.,* 1988) and cattle (Muinga *et al.,* 1992). Increasing levels of inclusion led to increase in the CP content of the diets (Yusuf, 2011). This apparent effect of dietary crude protein has also been reported by Rittenhouse *et al.* (1970), Muinga *et al. (*1995), Matejovsky and Sanson (1995) who demonstrated the influence of dietary crude protein or nitrogen level on DMI.

It is worth mentioning that the improvement of nutrients intake due to inclusion of mango leaves, may be related to the palatability of mango leaf to goat (Ajayi *et al.,* 2005). The mango leaves were probably more palatable and more acceptable to goats than the other two browse leaves (*Ficus thionningii* and *Gliricidia sepium***)**. Intake of basal hay, and therefore of the total diet, increased in accordance with the degree of substitution of cotton seed cake by Moringa Leaf meal. This could be due to an improved rumen ecosystem due to introduction of Moringa Leaf meal, leading to higher intakes (Murro *et al.,* 2003). Addition of fresh grass (Guttierrez and Elliott, 1984) or leucaena hay (Kabatange and Shayo, 1991) to a diet low in N and of low digestibility, improved the rumen ecosystem and fibre digestibility in sheep. Supplementation with Gliricidia leaves had a significant effect on daily Elephant grass (Napier grass) DM intake but did not significantly affect total DMI (g DM or g DM $kg^{-1}BW^{0.75}$). Mpairwe *et al.* (1998) reported that Gliricidia supplementation significantly decreased daily Elephant grass DMI. However, when daily Elephant grass DMI was expressed on metabolic body weight, there was no significant difference between the unsupplemented diet and diets supplemented at 4 and 8g. Supplementation substantially improved total crude protein intake (CPI) (g DM day^{-1} and g DM kg^{-1} $BW^{0.75}$). Higher levels of Gliricidia supplementation resulted in significantly higher CP intake than the lowest (4gDM kg^{-1}wt day^{-1}) level of supplementation but there was no significant difference between rations containing 8 and 12g Gliricidia DM kg^{-1} wt day^{-1}.

Optimum dry matter intake (DMI) is very important factor in ensuring the release of adequate nutrients for maintenance and production. With temperate grasses, voluntary food intake (VFI) directly affects their digestibility, but the relationship is less definitive for tropical species because of the different lengths of time required to digest tropical feeds. VFI has been shown to decrease with decreasing digestibility of dry matter within species for *Chloris gayana* and *Panicum* species (Devendra, 1990b). In terms of VFI, considerable variation exists between and within tropical grasses. Some of the variations are due to differences in digestibility but other unrelated factors such as those recorded for *Panicum* varieties may be involved. Rate of decrease in digestibility of younger tropical herbages is as high as in temperate species (Devendra, 1990a).

Devendra (1990b) indicated that the decline in digestibility with age of tropical grasses was more rapid than with tropical legumes which retained relatively high digestibilities at maturity. In the humid tropics, dry matter intake (DMI) is limited by the water content of, or the free water on, the ingested herbage. In the West Indies for instance, the dry matter content of herbage during the wet season was very low in Pangola grass (*Digitaria decumbens*) with a dry matter content of 23.4%, compared to 39.3% in the dry season, and such that the herbage contributed a high proportion of the total water consumed. Inadequate dietary energy intake arises from reduced DMI and is likely to occur when the DM content falls below 25%. Voluntary feed intake is influenced to a very large extent by the dietary crude protein content. It has been known for a long time that the protein content of most tropical forages is generally low (Devendra, 1990b). The protein content falls rapidly with maturity and reaches the lowest level before flowering. During the dry season, the crude protein levels fall to very low critical levels, even below 7% in the dry matter. The level critical to optimize rumen fermentation and microbial activity to optimize digestibility. Devendra (1990b) reported that the level of protein in the diet affects voluntary intake of food and low protein diets are generally not readily eaten by ruminants. Low CP resulted to low level of rumen degradable nitrogen (RDN) hence low microbial activity in the rumen which negatively impacts DM digestibility and microbial CP supply in the small intestine. In sheep, a crude protein content lower than 7% begins to limit intake. Leibholz and Kellaway (1984) have estimated that the minimum required crude protein of a poor quality diet with organic matter digestibility of 50% would be between 6.1 to 7.4%. Abdulrazak *et al.* (1997) reported that supplementation of maize stover with *Gliricidia sepium* or *Leucaena leucocephala* increased total DMI and stover intake at lower level of supplementation. Ondiek *et al.* (2013) indicated that intake of the basal diet ranged from 294 to 302g/d and this was similar across the treatments. The supplementation with *Acacia tortilis* and *Balanites aegyptiaca* significantly increased intake over the control, but supplemented groups were similar. Animals supplemented with *Acacia tortilis* consumed 449g/d compared to 442g/d and 249g/d for animals consuming *Balanites aegyptiaca* supplement and the control, respectively. This indicated that supplementation improved feed intake. Low DMD means long mean digesta retention time in the rumen (long mean retention time) which translates into low intake of DM. According to Egan (1986) legume supplements are usually most effective when offered with basal roughage containing less than 20g N/kg digestible organic matter, because they increase the rumen degradable nitrogen. Ondiek *et al.* (2013) also indicated a better response to the supplementation.

2.5 Digestibility

Digestibility tends to have a great influence on voluntary feed intake (VFI) of the basal forage. Digestibility of a feedstuff is affected by stage of maturity of the crop, botanical composition, dry matter intake (DMI) and dietary supplements, processing and treatment. It has been known for a long time that the more digestible a feedstuff is, the more it is eaten by the ruminants (Devendra, 1990b). This is the case that high digestibility increases DMI. Increasing digestibility means that high proportion of the feed is digested and absorption is more complete, with the volatile fatty acids (VFA) showing a lower proportion of acetic acid, the energetically lowest and least useful VFA, and with the presence of higher proportions of the more useful volatile fatty acids such as propionic and butyric acids. Digestibility of forage (browse and grass) depends on several factors such as the time of harvest, type of animal species and proportion of both grass and browse in the diet. Early digestibility trials with cattle on browse species on the Accra plains of Ghana indicated that organic matter and dry matter digestibilities ranged from 53-69% and 54-70%, respectively (Rose-Innes and Mabey, 1964). However, from preliminary experiments carried out in the Sahel zone of Mali, it appears that the digestion coefficients of some *Acacia* species (*A. albida* and *A. seyal),* and *Bauhinia rufescens* are in the range of 49-54% of dry matter. The inclusion of Moringa leaf had significant effect on apparent digestibility of DM, OM, CP, EE and CF. The digestibility was slightly higher in animal fed 30% Mango leaf. The highest digestibility on CP and EE were recorded in animals fed the 30% and consistently decreased as the level of Moringa leaf decreased and were statistically different. Alawa and Amadi (1991) showed that increasing of crude fibre in the diet decreases DM digestibility. McDonald *et al.* (1995) also reported that the decrease in crude fibre and ether extract digestibility as a result of the increase of crude fibre in the feed. The highest DM digestibility was obtained in animals fed 30% Mango leaf diet (Yusuf, 2011). Ademosun *et al.* (1988) demonstrated that graded levels of browse (*leucaena or gliricidia*) mixed with native grass for WAD goats improved digestibility compare to the control. Murro *et al.* (2003) reported that, digestibility of DM, OM and cell wall constituents were higher for diet with the M100 supplement compared with diets having lower levels of Moringa Leaf Meal. Mpairwe *et al.* (1998) demonstrated that Supplementation improved dry matter and crude protein digestibility of the total rations. Total dry matter digestibility significantly increased with increasing levels of Gliricidia and the highest digestibility coefficient (60.5%) was recorded for sheep supplemented at 8g gliricidia DM kg^{-1} live weight day^{-1}. However, there was no significant difference in DM digestibility between treatments receiving 0, 4 and 12 g DM kg^{-1} live weight day^{-1} Gliricidia supplements. Crude protein digestibility of the supplemented rations was significantly higher than the unsupplemented ration but there was no significant difference in CP digestibility between the gliricidia supplemented diets. The highest CP digestibility (74.4%) was recorded with the 8g level of supplementation.

2.6 Live weight gain

Different forms of supplement significantly improve average daily gain, mature body weight and feed conversion efficiency of small ruminant animals. Growth rate was higher when Moringa Leaf Meal replaced all the Cottonseed cake in the supplement (Murro *et al.,* 2003). Das and Sendalo (1991) and Kifaro *et al.* (1996) considering the type of hay fed, the rates of live weight gain (52 to 62 g/d) are acceptable and fall in the range of 40 to 65 g/d for Black Head Persian (BHP) sheep from birth to 72 weeks on *Chloris gayana* hay supplemented with *Leucaena leucocephala.* The feed conversion reported was poorer on the diets of meal (M) 66 and M (100) compared with M (0) and M (33) (Murro *et al.,* 2003). An average daily weight gain of 17.9, 80.4, 89.3 and 71.4 g day^{-1} for the 0, 4, 8, and 12g levels of gliricidia supplementation were recorded by Mpairwe *et al.* (1998). Aganga and Tshwenyane (2003) demonstrated that Tswana goats consumed forages at 3.3 - 3.8% of their body weight while Ndemanisho *et al.* (2007) showed values of 2.8 - 2.9% for goats fed maize stover and supplemented with rations containing Leucaena, Albizia, Moringa and

Gliricidia leaf forages. The ADG of the control animals were low (8.33g/d) and initially the animals lost weight due to adjusting from free grazing to confinement and restricted feeding with no free choice to forage. The supplemented diets resulted to significant ADG changes, and were highest for the *B. aegyptiaca* supplement (Ondiek *et al.,* 2013). Ndemanisho *et al.* (2007) reported higher values 22.1±3.18 to 25.4±3.09 g/d for crossbred dairy goats fed maize stover and tree browse - based supplements and 33.1±3.09 g/d for goats fed cotton seed cake -based supplement. However, these were lower than the earlier reports for goats fed treated maize stover (Ndemanisho *et al.,* 1998) or rice straw (Mgheni *et al.,* 1993).

2.7 Nitrogen metabolism

In ruminants, feed is mainly digested in the rumen, which causes the growth of a microbial population which, in turn, is digested in the lower tract, thereby benefiting the host animal. The primary source of nitrogen for rumen microbes is either protein or non-protein nitrogen from feed. Most of this is converted to ammonia and then incorporated into microbial cells (Ørskov, 1982). The ability of rumen microorganisms to use ammonia depends on adequate supply of energy (fermentable OM). The energy must be available at the same time as the ammonia; otherwise the ammonia will not be effectively utilized. Excess ammonia in the rumen is absorbed across the rumen epithelium into the blood and converted to urea by the liver and excreted through urine. The rumen microorganisms convert nitrogen into microbial cells, irrespective of whether the nitrogen originated as protein or as non-protein nitrogen unusable by the host. The conversion of feed nitrogen into microbial cells is obviously an advantage to the animal in the case of non-protein nitrogen. Nevertheless, it is wasteful if the nitrogen source is of high-quality protein because most nitrogen in bacterial cell walls is indigestible (Ørskov, 1982), resulting in a net loss of nitrogen available to the host. High quality protein when degraded in the rumen can be wasteful in several ways; excess ammonia lost via urea in urine nor all ammonia will be captured. The preformed protein would have formed a good source of amino acids or protein of higher quality than the microbial crude protein whose cell walls may not all be digestible. Microbial and escape protein from the rumen may be digested in the lower tract and absorbed by the host. Protein bound in plant cell walls or in chemical complexes is not absorbed. The unabsorbed protein, as well as endogenous nitrogen from the digestive tract and recycled urea, may be available to microorganisms in the large intestine (Visek, 1968; Beever *et al.,* 1974 and Nolan, 1975).

However, the incorporation of nitrogen into microorganisms in the lower tract depends on the energy source which escapes absorption (Beever *et al.,* 1974 and Van Soest, 1982). Faecal nitrogen is composed of undegraded feed nitrogen, microbial nitrogen from the rumen and large intestine, and endogenous nitrogen from the digestive tract but, not incorporated into microbial nitrogen (Van Soest, 1982). The size of these fractions depends on the content of protein and energy in the diet, rate of passage, and the nutritional status of the host (Mason, 1979). Faecal material originating from microbial and endogenous sources can be separated from other faecal material by its solubility in neutral detergent fibre (Mason, 1969). Higher total faecal nitrogen was reported for all diets containing tanniferous feeds. The higher faecal NDF-N values can be attributed to indigestible tannin-protein complexes (Rittner, 1987; Tanner, 1988 and Woodward, 1988). Reed and Soller (1987) reported high levels of faecal nitrogen in sheep fed diets containing *Acacia seyal.* This fraction, also called the metabolic increment, is nitrogenous material of endogenous origin, and may result from a higher production of rumen microbes as a consequence of greater recycling of urea from blood to rumen.

According to Abdu *et al.* (2012), the findings on nitrogen balance indicated significant differences in fecal nitrogen output; *Acacia auriculate* had higher fecal nitrogen (16.76 g/d), followed by *Butryospermum parkii* (12.42 g/d) and *Albizia lebbeck* and *Gmelina arborea* which had 9.95 and 7.70 g/d, respectively. The very high fecal nitrogen in *A. auriculate* indicates very strong tannin activity resulting in dietary nitrogen being excreted in the feces as tannin-protein complexes. The reduced nitrogen retention in animals fed *A. auriculate* was associated with its high tannin levels. Ben Salem *et al. (*1997); Ebong (1995); and Woodward and Reed (1997) working on *Acacia saligna*, *Acacia seyal* and *Acacia brevispica* respectively, reported that, reduced nitrogen retention in animals was due to high tannin levels in the feed. Total nitrogen output was significantly higher in *A. auriculate* (20.65 g/d), followed by *B. parkii* (18.67 g/d), while the lowest was reported in *G. arborea* and *A. lebbeck*, which were statistically similar (Abdu *et al.,* 2012). The increased total nitrogen output observed in animals fed *A. auriculate* is a necessary consequence of decreased nitrogen absorption caused by high contents of tannin in feed (Harrison *et al.,* 1973; Reed and Soller, 1987; Fassler and Lascano, 1995; and Woodward and Reed, 1997). Nitrogen retention summarizes the value of a feed as a source of nitrogen. Woodward (1988) demonstrated that when

A. brevispica and *S. sesban* were each fed at three levels in combination with vetch and teff straw, the amount of retained nitrogen was higher for all diets containing browse than for vetch alone. Nitrogen retention increased as a linear function of intake of *S. sesban,* but increased then decreased as a function of intake of *A. brevispica.* The quadratic term in the regression of retained nitrogen on intake of *A. brevispica* was significant (Woodward, 1988). Partitioning of intake nitrogen among faeces, urinary and retained nitrogen explains the difference between *S. sesban* and *A. brevispica* (Woodward, 1988). For diets including *S. sesban,* urinary nitrogen increased with increasing proportion of browse in the feed, but remained a constant fraction of intake nitrogen. Also, metabolic nitrogen (g/d) did not vary but decreased as a fraction of intake. Therefore, nitrogen retention increased steadily. The result of nitrogen retention showed *B. parkii* to be significantly higher, followed by *G. arborea* and *A. lebbeck* which were similar, while *A. auriculate* had the lowest nitrogen retention (Abdu *et al.,* 2012). Reed *et al.* (1990) indicated that, nitrogen retention vary depending on the inclusion of tannins in the diet.

2.8 Potential and limitations of the use of browse in ruminant feeding

In free ranging systems, browse species constitute an effective insurance against seasonal feed shortage in the dry season, supplementing the quantity and quality of pasture. Trees and shrubs are perennials allowing the provision of permanent fodder compared to herbaceous species, which decrease rapidly in quantity and quality during the dry season. Through their deep root system, trees are able to access subterranean water located deep in the soil and therefore continue to grow under dry conditions and keep leaves green. The regular availability of forage from trees and shrubs depends on the diversity of species and their phenological variation in time and space (Grouzis and Sicot, 1980). On the other hand, their high feeding quality in terms of protein and some minerals such as calcium and phosphorus is well anticipated (Paterson *et al.,* 1998). Almost all literature on the use of shrub and tree fodders to supplement basal roughage of natural grasses or crop residues has shown positive responses with respect to the productivity of cattle, sheep and goats (Norton, 1998). Also, stocking rates are shown to increase generally when fodder trees are included in the pastures (Leng, 1997). The potential use of browse as source of bypass protein to increase productivity of ruminants where bypass protein supplements in the form of concentrates such as cottonseed meal have been fed to ruminants, supplementing poor quality forages (Leng, 1997). This process has been linked to the effect of condensed tannins that are bound to foliage protein, preventing the microbial degradation of leaf protein in the rumen. Once the particles high in protein move to the lower digestive tract, some of the condensed tannin complex with protein may be hydrolyzed, allowing protein to be digested and absorbed into the body tissue. Condensed tannins under acid or alkaline conditions of the intestines may be split to sugars and organic acids, mostly gallic acid, releasing protein and amino acids that are digested in the lower gut. Anthelmintic properties have been reported in many browse plants (Hammond *et al.,* 1997), that by improving the nutritional status of the animals increase their ability to resist the harmful effects of parasites (Hoste *et al.,* 2006). The utilization of browse is limited by the high lignin content and the presence of anti-nutritional factors, which may be toxic to ruminants. Many browse species have chemicals that are produced to prevent invasion or consumption of their leaves by microbes, and defoliating insects and herbivores. The most recognized is tannin, which is shown to decrease the digestibility in browse fodders. Tannins are a group of polyphenol substances with the ability to bind protein in liquid form.

They are classified into two groups; hydrolysable or condensed tannins are considered to have both unfavourable and beneficial effects depending on their concentration and nature, animal species, physiological status of the animal and the composition of the diet (Makkar, 2003). Silanikove *et al.* (1996) concluded that goats have the ability to consume large amounts of tannin rich plants without exhibiting toxic syndromes (due to a high proline and hydroproline enzymes content in the saliva), which is not the case for other ruminant species. These amino acids in saliva are known to bind tannins. The negative effect of tannin is seen in lowered feed intake, directly due to the astringent properties of tannin rich feed, and indirectly by reducing the digestibility of the feed. Tannin reduced the digestible crude protein by 44% and digestible organic matter by 14% (Hanley *et al.,* 1992). Ebong (1995) explained that, the level of digestibility reduction varied depending on the level and the activities of tannin. A level of tannin below 5% seems to be tolerable for ruminant animals. Tannins are the best known of the anti-nutritional factors of browse, and the secondary compounds include; cyanide, nitrate, fluoroacetate, cyanogenic glycosides, saponins, oxalates, mimosine and various sterols (Leng, 1997). Nevertheless, the toxic compounds seem to become of nutritionally significance only when the plant constitutes a high proportion of the diet. As a result, the effects of high protein forage could counteract the effect of the toxic compounds when used as supplement in the diets. Papanastasi *et al.* (2002) concluded that performance of animals fed with fodder trees and shrubs depends on the particular animal and plant species. Therefore, maximum performance can be achieved if the adverse effects of tannins are overcome by using additives or if shrubs are combined with other herbaceous species.

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CHAPTER THREE

Predominant and most preferred indigenous tree browses used as feed for Ruminant livestock in South Sudan

Abstract

Livestock is one of the important food sources in South Sudan, however, animal productivity is very low particularly in dry season due to lack of adequate feed. South Sudan has diverse feed resources in form of browses. However, they have not been fully used often for lack of technical knowledge. Therefore, this study was carried out to identify the abundant and most diversified and preferred browse species for livestock feeding in dry season. The study covered three locations of Juba, Yei and Kajo-keji counties of Central Equatoria State, one of the ten (10) states of the Republic of South Sudan. A total of one hundred and fifty (150) structured questionnaires were administered to fifty (50) livestock keeping households/respondents randomly selected in each county. Data collected was subjected to analysis using SPSS for descriptive statistics (frequencies, means and percentages). The results are presented in tables, pie and bar charts where necessary. In the study, results were obtained for respondent's characteristics, livestock ownership and production objectives; livestock management systems; types of land tenure for livestock grazing; abundant, diversified and most preferred trees and shrubs by the livestock; and feed resources and feeding strategies applied during different seasons. In all, twenty five (25) browse species were identified by the respondents in all the counties. Livestock keepers also classified the browses utilized in wet (rainy) and dry seasons and those particularly used by their livestock. The results of this study indicated that livestock owners are knowledgeable about different browse species and the particular feed components used by different livestock species. The study indicate there is a diversity of various tree species that could serve as important sources of supplementary feeding particularly in dry season. In conclusion, livestock keepers should be encouraged and trained on utilization of browse resources as feed for livestock, especially in times when grasses become scarce.

Keywords: browses, dry season, feed, indigenous**,** livestock

3.1 Introduction

Generally, the major grazing environment in the Republic of South Sudan (RSS) is tropical woodland savanna with very rich grasslands, trees and shrubs. These natural rangelands represent an important forage resource for livestock in Central Equatoria State (CES). Le Houerou (1980) reported that in tropical savanna, browses are the main animal feed during critical seasons particularly on ranges where grasslands are associated with open stands of browses (trees and shrubs). Browse refers to leaves, twigs, flowers and pods. Livestock which is a major source of livelihood in the country, is entirely dependent on the natural rangelands which is composed of grasses, trees and shrubs. Browses are the most economical source of nutrients for livestock, particularly goats. Goats, being natural browsers, have the unique ability to select plants that are in their most nutritious stage. Goats that usually browse have less problems with internal parasites. Pastures tend to be high in energy and protein when in a young vegetative stage, but as plants mature, palatability and nutritive value declines. According to Schoenian (2009), at the early part of the grazing season, browse species tend to be higher in energy and protein than ordinary pasture. There is scanty published information available on browse forage resources in South Sudan. The objective of this study therefore, was to identify the most predominant and preferred indigenous tree browses fed on by ruminant livestock in the Central Equatoria State of the Republic of South Sudan.

3.2 Methodology

3.2.1 Description of the study area

The study area is located in Central Equatoria State (CES), South Sudan. Browse samples were collected from Juba, Kajo-Keji and Yei Counties of CES. The CES is one of the Ten (10) States of South Sudan and constitutes Equatoria Region. It covers an area of 45,025 Km², of which 770 Km² is a home reserve, while 756 Km² and 31,199 Km² are forests and arable land, respectively (SMARF, 2010). The population of CES is estimated at 1,103,592 (Sudan National census, 2008). The CES lies between 30°-30 and 60° North latitudes and between 30°-30 and 32° East longitudes at the extreme South Sudan. CES is boardered by Eastern Equatoria State to the East, Jonglei state to the North East, Lakes State to North West, Western Equatoria state to the west, the Democratic Republic of Congo (DRC) to the South West and Uganda to the South East. The State is drained by several rivers which empty into the White Nile which traverses the State from South to North.

The State has a hilly topography with a humid climate. The average rainfall is 1000 mm, and is received between April and November. The period between December to March is dry Season. The soils are sandy, red iron stone plateau to black, good drainage at high ground and water logged at plains, especially the Eastern lowlands through which the River Nile flows. The state has predominantly deciduous to evergreen vegetation interspersed with economically valued hard wood forests, Bamboo, Gum Arabic, Neem and Mango trees.

The State is inhabited by 14 ethnic groups; the Bari, Kuku, Pojulu, Nyangwara, Kakwa, Keliko, Baka, Mundu, Avokaya, Lubgwara, Adio, Mundari, Lokoya and Lulubo. The Bari speaking ethnic groups are mainly agro-pastoral tribes, whose livelihood is based on subsistence agriculture and livestock keeping (SMARF, 2010). The livestock reared by these communities include cattle, sheep, goats, pigs and poultry. Ruminant livestock population is estimated at 2 million cattle, 1.2 million goats and 1million sheep. The predominant cattle breed is the *Bos indicus* of which Nilotic type a zebu is predominant, characterized by low milk production, and mainly beefy type is dominant. There exists also the dwarf type which is resistant to tsetse flies. The breeds of goats and sheep are not yet characterized, but they are dwarf with low milk production and are highly prolific.

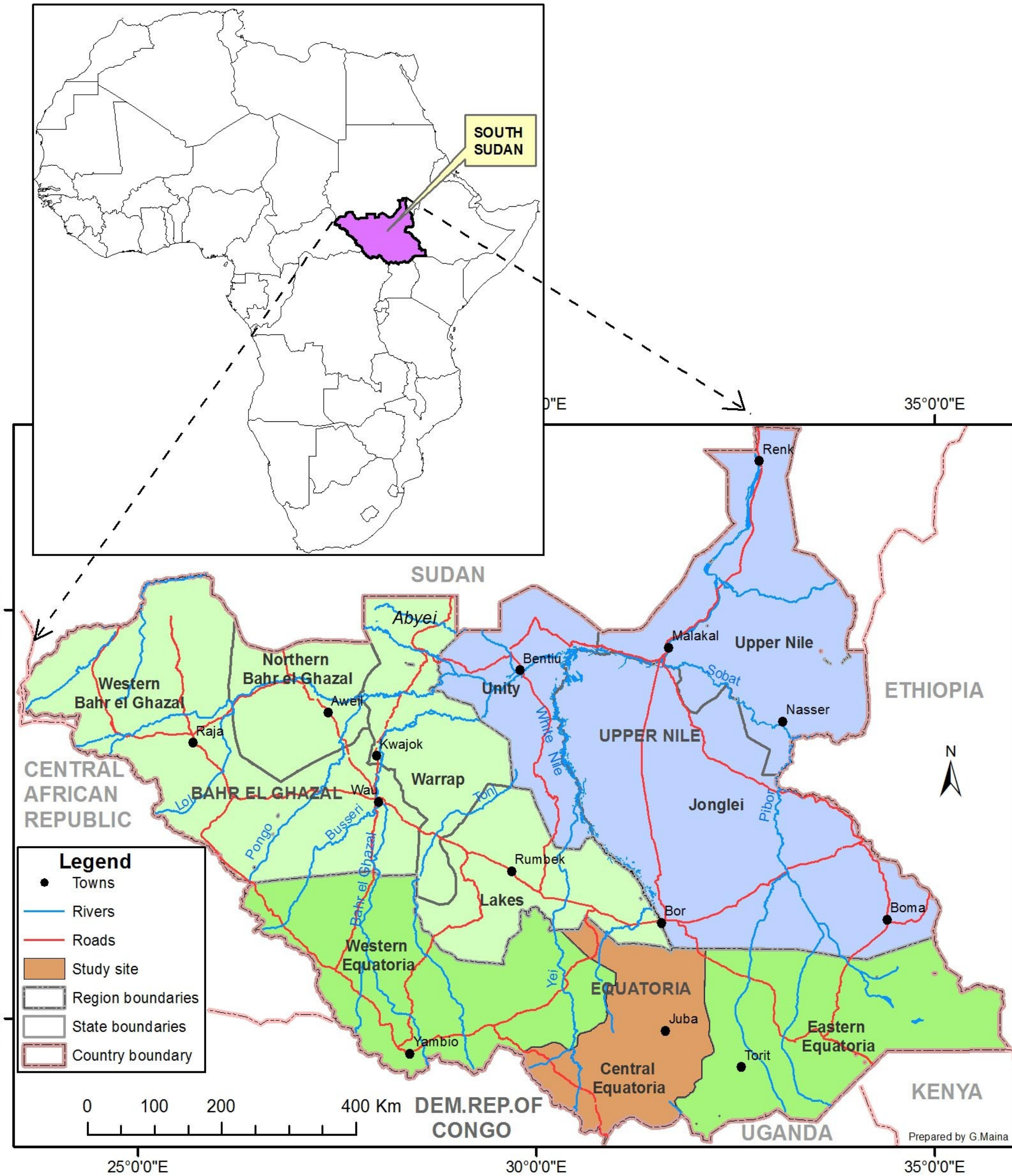

Figure 1. Location of the study area in South Sudan

Source: Republic of South Sudan Towns and States Map

3.2.2 Data collection

Field survey using a structured questionnaire was conducted in three purposively selected counties of Juba, Yei and Kajo-keji in CES. Sampling was based on accessibility and people's willingness to participate in the studies. Average households in each county were about five hundred (500) and almost every household owned livestock, particularly small ruminants (goats and sheep), pigs, chicken and cattle, and as such each county was covered with fifty (50) questionnaires representing (10%) of the total households. The individual herds formed the sampling units and the herd owners interviewed provided the primary information. Thus, a detailed questionnaire was administered to the 150 respondent households. Livestock keepers were selected randomly based on the nearest individual method of which 50 respondents were surveyed in each county. Livestock owners' knowledge on browse forage and their preference by cattle, goats and sheep was recorded. Species names were recorded in local language and later identified by their scientific names. The questionnaire was made up of open and closed-ended questions mainly on browse species and their utilization by the livestock. During the survey, focus group discussions were also held with livestock keepers to identify browse species regarded as important livestock feed. Browses reported were those indicated by the respondents surveyed and within focus group discussion as abundant and most preferred by livestock in the county.

3.2.3 Data analysis

Data obtained from the survey was entered into excel sheets and exported to SPSS software (SPSS version 20; 2011) and then cleaned to ensure completeness prior to analysis. The parameters for which descriptive statistics was obtained were; personal characteristics (gender, age, education and major occupation), importance of livestock to the respondent compared to other sources of livelihood, acquisition of foundation herd, livestock management systems, factors encouraging keeping of livestock around urban centres, types of land tenure, important feed resources for livestock and feeding strategies applied during times of moderate to severe shortage.

3.3 Results

3.3.1 Respondents Characteristics

The results on personal characteristics are presented in Tables 6 and 7. The results of the survey indicated information obtained was reliable because of the respondent's maturity as majority were from the age 41 – 60 years (Table 6). The respondents were able to identify the various indigenous browse species in local languages (Table 9). The results of the survey on socio-economic status highlighted gender significantly ($P < 0.01$) influenced livestock ownership. The majority of livestock keepers were male (82.2%). Most of the livestock keepers interviewed were literate having attended primary (56.6%) and secondary (27.9%) schools. However, 11.6% of livestock owners have no formal education. The results of the survey also indicate livestock keeping as the major form of livelihood (20.2%) whereas 34.9% of the respondents were engaged in other livelihood activities such as urban migration, hunting and crop cultivation (Table 7). The results showed that the people in the targeted counties of CES are aware of the importance and abundance of indigenous tree browses and their utilization by different species of livestock (Table 9).

Table 6. Age groups of the respondents surveyed in Central Equatoria State of the Republic of South Sudan

Age group (Years)	n	Respondent (%)
< 20	4.0	2.6
21 – 40	40.0	26.9
41 – 60	73.0	48.7
> 60	33.0	21.8

Table 7. Characteristics of livestock owners in the selected study counties of Central Equatoria State of the Republic of South Sudan

Characteristics		**n**	**Respondent (%)**
Gender	Male	123.0	82.2
	Female	27.0	17.8
Education Level	None	17.0	11.6
	Primary	85.0	56.6
	Secondary	42.0	27.9
	College	5.0	3.1
	University	1.0	0.8
Major occupation	None	23.0	15.5
	Livestock	30.0	20.1
	Business	17.0	10.9
	Employment	28.0	18.6
	Others	52.0	34.9

3.3.2 Importance of livestock compared to other sources of livelihood

The relative importance of livestock compared to other sources of livelihood is presented in (Figure 2). Generally, small ruminants (sheep and goats) are regarded as most important livelihood sources in the study counties of CES. The majority of respondents indicated the importance of livestock in their livelihood followed by crop farming. The results of the present study indicated business and formal employment as less important, while remittances are of least importance (Figure 2). Comparisons amongst various livelihood sources indicate that goats and sheep are highly important sources of livelihood in CES.

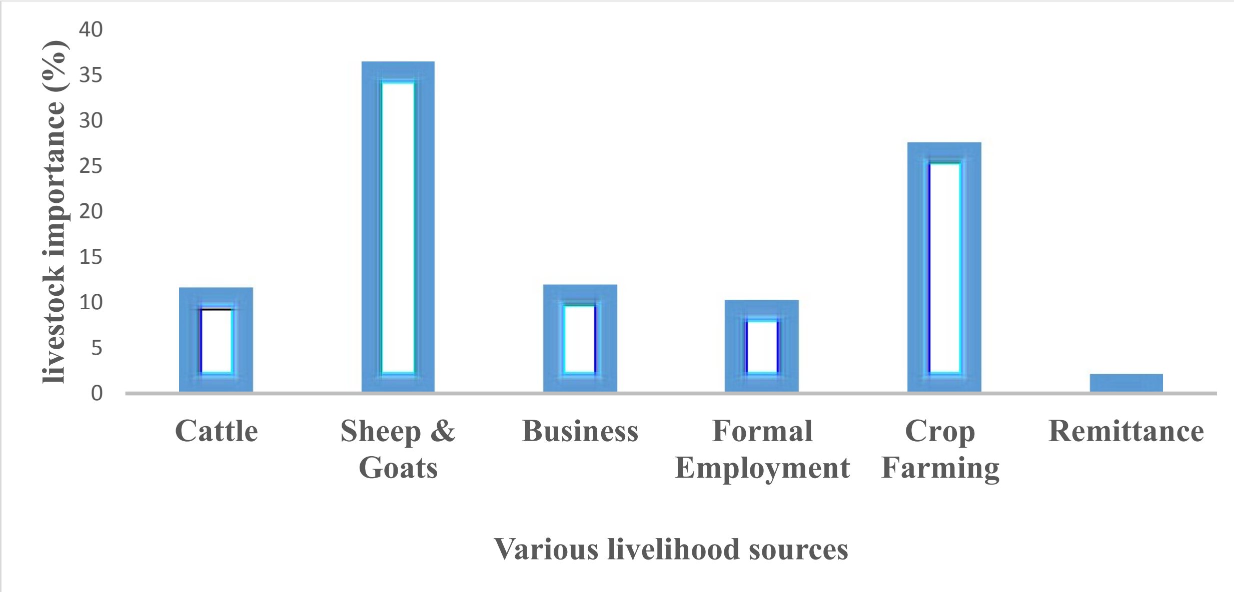

Figure 2. Importance of various livelihood sources amongst the respondents surveyed in Central Equatoria State of Republic of South Sudan.

3.3.3 Acquisition of livestock foundation herd

The sources of foundation livestock herds are shown in Table 8. Results indicate 58.1%, 22.5% and 19.4% of respondents acquired their foundation stock/herd through purchase, inheritance from the family, and both purchase and inheritance, respectively (Table 8). The majority of the respondents purchased their foundation stock. In terms of herd structures, there is higher proportion of adult female livestock kept by the owners (Figure 3).

Table 8. Sources of foundation herds for livestock keepers in Central Equatoria State of the Republic of South Sudan

Sources of foundation herd	n	Respondents (%)	Chi-square test	
			χ^2- value	*p*-value
Purchase	87.0	58.1	19.1	0.001
Inheritance	34.0	22.5		
Inheritance and purchase	29.0	19.4		

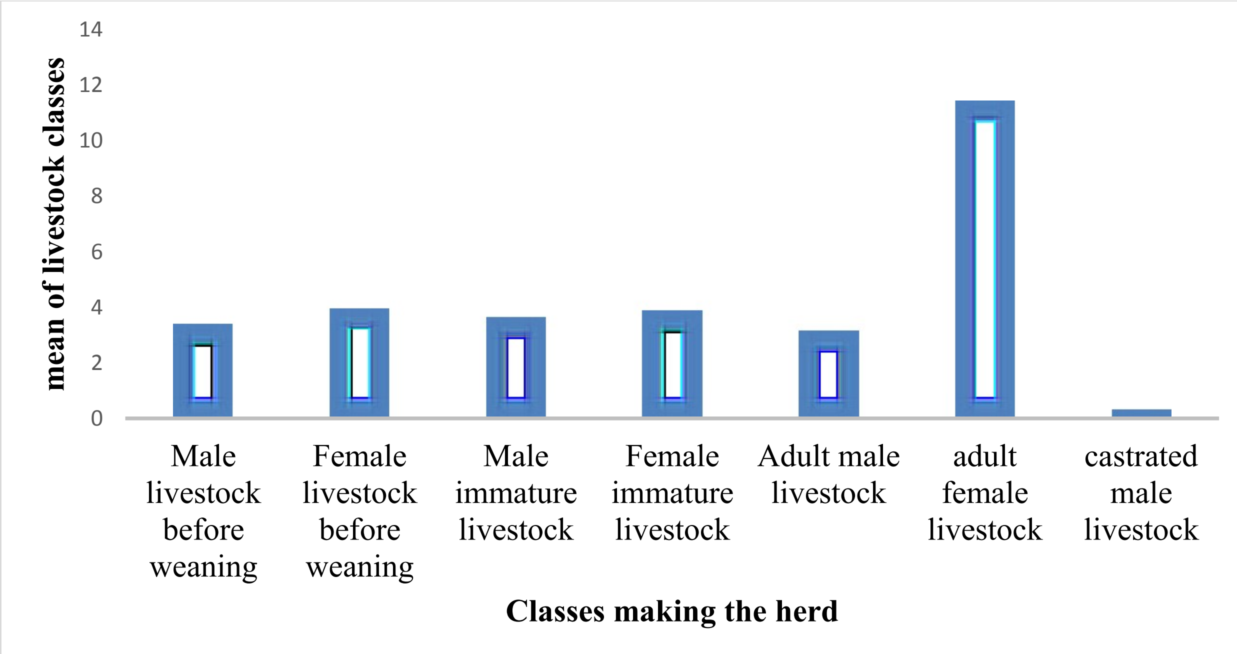

Figure 3. Mean proportions of different animal groups making the livestock herd in the study counties of Central Equatoria State of the Republic of South Sudan.

3.3.4 Livestock production systems and land tenure in CES of South Sudan.

The survey results indicated 92% of the livestock keepers practiced peri-urban/semi-sedentary system compared to 8% that were engaged in pastoral system (Figure 4). This is a true reflection of the Country's livestock production systems. Majority of the livestock keepers kept livestock around urban centers due to easy access of services (Figure 5). In this study, communally owned land provided important grazing areas for livestock (Figure 6).

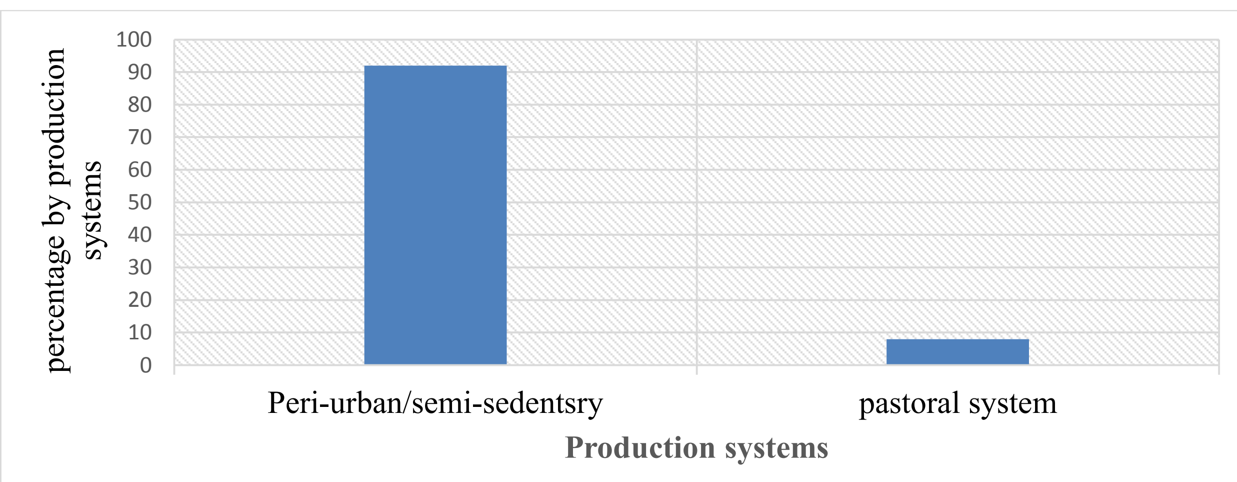

Figure 4. Livestock production systems in Central Equatoria State of the Republic of South Sudan.

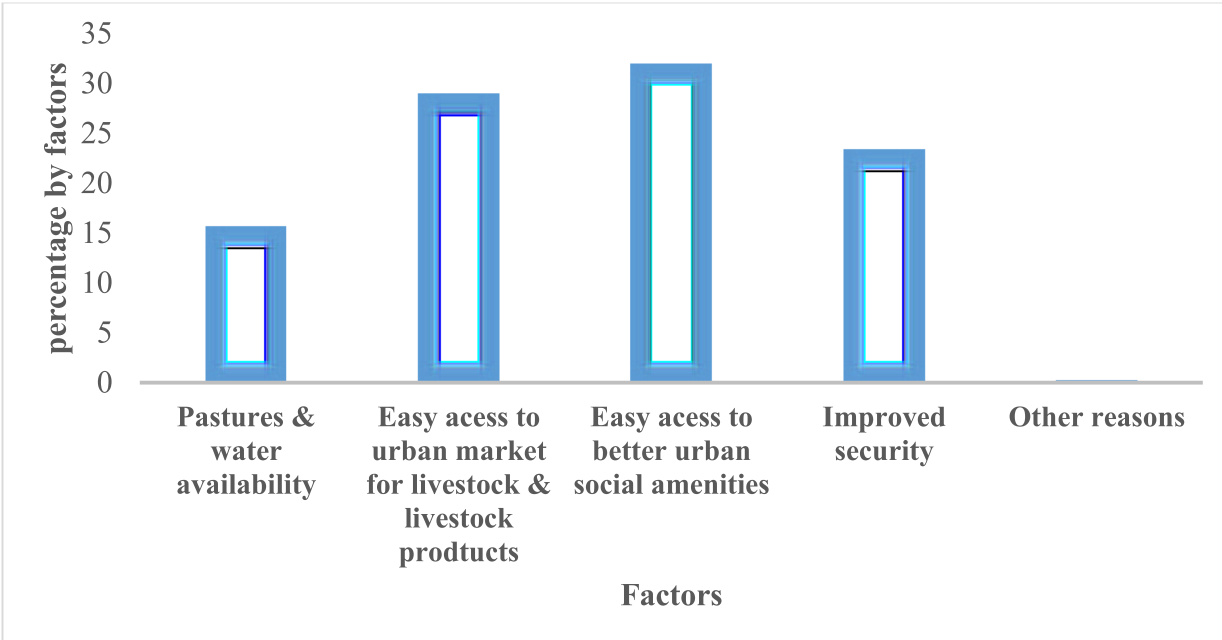

Figure 5. Factors encouraging keeping of livestock around urban centres in the surveyed areas of Central Equatoria State of South Sudan.

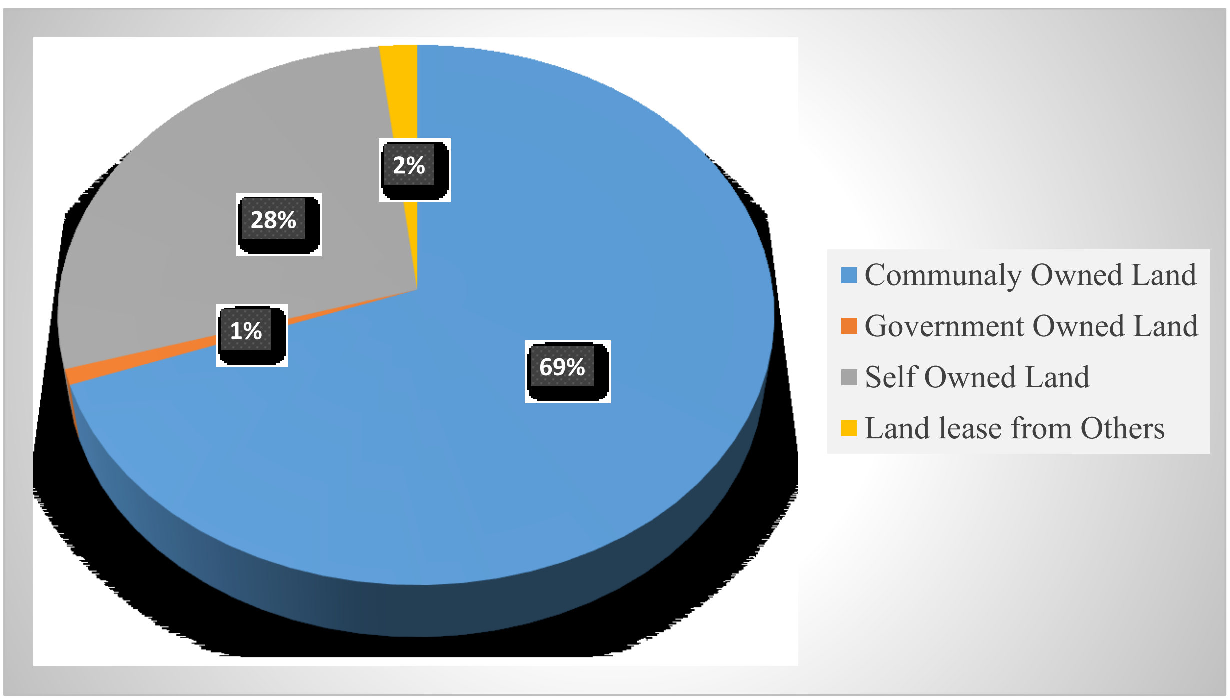

Figure 6. Types of land tenure for grazing livestock in Central Equatoria State of South Sudan

Table 9. Indigenous browse forages predominantly fed on by Ruminant livestock in Central Equatoria State of the Republic of South Sudan

S/No	Botanical name	Vernacular name	Part utilized	Animal species utilizing it
1.	*Acacia ataxacantha*	Morgini	Leaves	goats
2.	*Acacia borleae*	Bukuli	Leaves, Fruits, Bark	cattle, goats, sheep
3.	*Acacia davyi*	Kadap	Leaves	Goats
4.	*Acacia nilotica*	Reriya	Leaves	Goats
5.	*Afzelia Africana*	Beleng	Leaves, fruits	Cattle, goats
6.	*Azadirachta indica*	Nima	Leaves, fruits	Goats
7.	*Balanites aegyptiaca*	Lalook	Leaves, fruits	Cattle, goats
8.	*Bauhinia variegate*	Pepe	Fruits	Cattle
9.	*Butyrospermum paradoxon*	Kumuri	Fruits	Cattle, goats
10.	*Combretum adenogonium*	Gwagwat	Leaves	Sheep, goats
11.	*Ficus altissima*	Kumi	Fruits	Goats
12.	*Ficus abutilifolia*	Muteru	Leaves	Goats
13.	*Ficus congensis*	Bule	Fruits	Goats
14.	*Ficus enormis*	Kuwi	Fruits	Goats
15.	*Ficus sycomorus*	Biyotat	Fruits	Goats
16.	*Ficus Vasta*	Teki	Fruits	Goats
17.	*Kigelia africana*	Unguli	Flowers	Goats
18.	*Oxytenanthera abyssinica*	Kiriyo	Leaves, fruits	Cattle, goats
19.	*Sclerocarya birrea*	Lukwoki	Leaves, fruits	Cattle, goats, sheep
20.	*Tamarindus indica*	Peta/Kite	Leaves, fruits	Goats
21.	*Terminalia avicenniodes*	Nyangilo	Leaves	Cattle, goats
22.	*Terminilia ssp*	Kobetat	Leaves	Goats
23.	*Trichilia eructica*	Kurilang	Fruits	Goats
24.	*Ziziphus spina-Christi*	Lagat/Nabak	Leaves, fruits	Goats
25.	*Ziziphus mucronata*	Puruti	Leaves, fruits	Goats

Table 10. Browse forages utilized by livestock during wet and dry seasons in Central Equatoria State of the Republic of South Sudan

Wet season browses	n	Respondents (%)	Dry season browses	n	Respondents (%)
Ziziphus spina-christi	22.0	33.0	*Ziziphus spina-christi*	23.0	34.0
Combretum adenogonium	19.0	28.0	*Acacia nilotica*	17.0	25.0
Acacia nilotica	16.0	24.0	*C. adenogonium*	14.0	21.0
Bauhinia variegate	12.0	18.0	*Balanites aegyptiaca*	11.0	17.0
Acacia borleae	7.0	11.0	*Sclerocarya birrea*	9.0	14.0
Sclerocarya birrea	7.0	10.0	*Acacia borleae*	8.0	12.0
Balanites aegyptiaca	5.0	8.0	*Acacia davyi*	7.0	10.0
Acacia davyi	5.0	7.0	*Afzelia africana*	6.0	9.0
Tamarindus indica	4.0	6.0	*Tamarindus indica*	3.0	5.0
Oxytenanthera abyssinica	3.0	5.0	*Kigelia africana*	2.0	3.0

4.3.5 Important feed resources for livestock and strategies to cope with feed shortage.

The relative importance of various forage feed types as feed for livestock in CES is presented in Figure 7. The results suggest that livestock depend entirely on the rangelands (natural pastures and browses) for grazing with minimal use of crop residues (Figure 7). Native grasses are the main forage types available to livestock compared to other sources of feeds as assessed by 48.9% of the respondents. However, native grasses and browses (trees and shrubs) are the main sources of forage for livestock. The study also indicate that crop residues constitute another source of feed available for livestock (14.8%). The importance of grasses was significant compared to other feed resources available. The respondents indicated some strategies to overcome feed shortage. The majority (67.5%) of the livestock owners mentioned prolonging daily grazing time and splitting the herd for preferential feeding (Figure 8). Prolonging daily grazing to cope with feed shortage is highly important among other strategies.

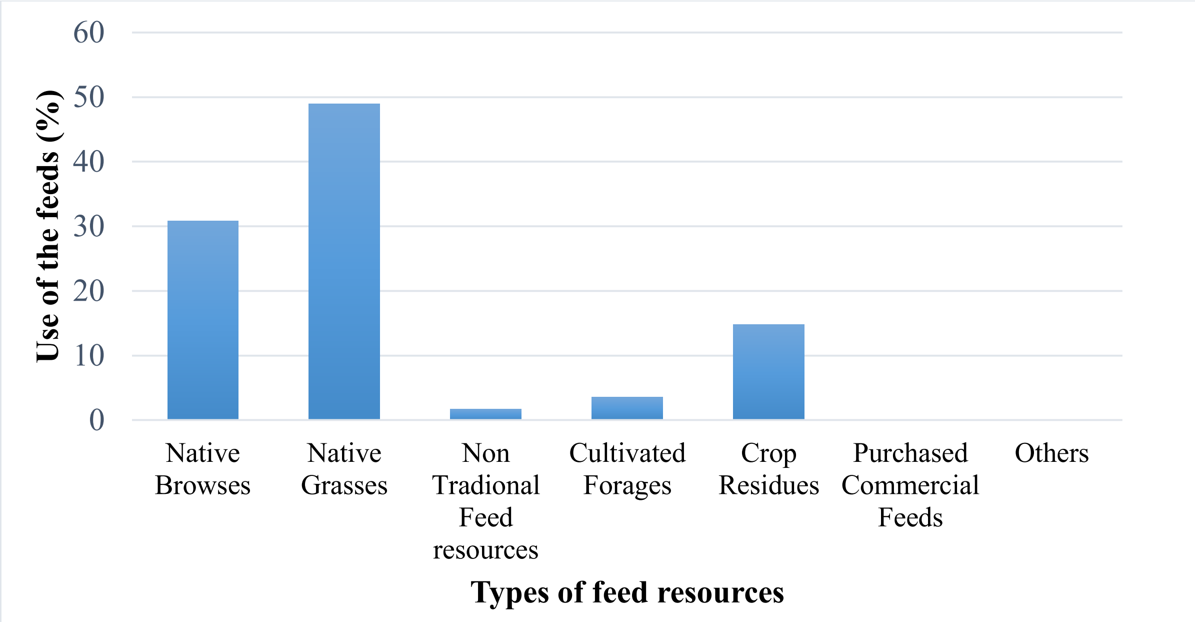

Figure 7. Types of feedstuffs for feeding livestock in Central Equatoria State of the Republic of South Sudan

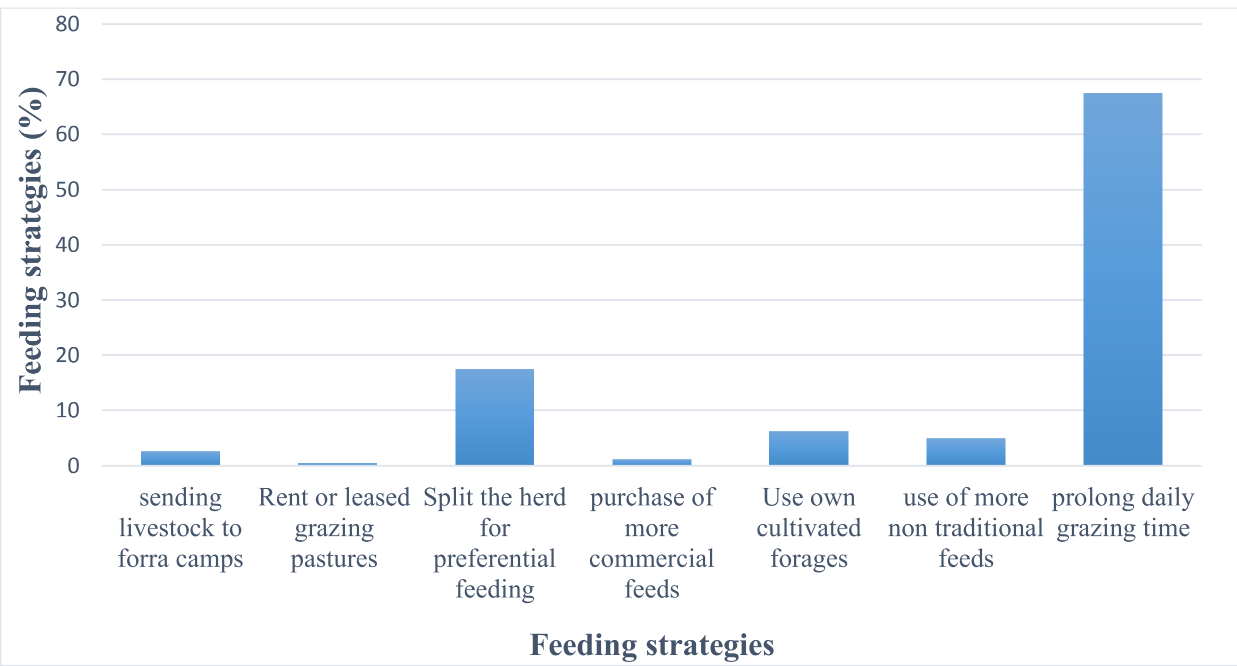

Figure 8. Feeding strategies during times of moderate to severe shortage in Central Equatoria State of Republic of South Sudan

3.4 Discussion

3.4.1 Respondent's Characteristics

The results of the present study indicated that majority of the respondents were aged above 41 years which enhances the reliability of the information obtained (Table 6). This is because the maturity of the respondents enables them to have good knowledge of the geography of the area. Most of the youth between the ages of 21-40 preferred other income generating activities associated with migration to urban centers (Ansah and Nagbila, 2011**).** Livestock and livestock products as well as feed resources received little attention with regards to research and development in CES of South Sudan. This could be due to the fact that South Sudan mostly rely on oil production as the main source of income. Although livestock play an important role in the livelihood of most South Sudanese people and thus contributes to food security, policy makers have given little attention to the development of this sector.

In the present study, gender significantly influenced livestock ownership in the counties studied, where males are the majority in livestock management activities (Table 7), although females also played a significant role. This could be attributed to the role livestock play in the life of South Sudanese communities. Similar results were reported by Preston (2008), Ansah and Nagbila (2011), Gaiballa and Lee (2012), and Noor *et al.* (2012). Keeping livestock around urban centers like Juba, Yei and Kajo-Keji where services are easily available coupled with the possibility of generating income from the sale of livestock and their products may have encouraged women to keep livestock in CES of South Sudan.

In the current study, majority of the respondents attended primary school and only 11.6% have never gone to school (Table 7). This implies that majority of the livestock keeping communities were engaged in livestock activities that render them little opportunity to attend post primary school. These findings are consistent with reports by Noor *et al.* (2012), who reported that the lifestyle of most pastoral communities who depend on livestock involves regular movement in search of pastures and water for their animals. This lifestyle is not favorable for formal education and may be the reason for the high percentage (56.6%) of livestock keeping households with only primary education. Livestock keeping is the major form of occupation of the interviewed respondents in CES. These results agree with Noor *et al.* (2012) whose study was on camels keeping in northern Kenya. However, livestock is not the only livelihood activity. Other activities include business, formal employment, and others minor activities such as fishing, hunting and cultivation.

3.4.2 Importance of livestock as a source of livelihood

In the present study, the majority of the livestock owners indicated that sheep and goats are of significant importance to their livelihood compared to other sources such as cattle, business, formal employment, crop farming and remittances. These findings agree with those of Guliye *et al.* (2007) and Noor *et al.* (2012). This could be due to ease of managing sheep and goats compared to cattle. Besides, cattle usually invite more insecurity due to prevalent cultural practice of livestock rustling. Moreover, sheep and goats are easily sold when need arises, for instance when there is crop failure, need for medication and other social amenities. The importance of sheep and goats is shown by the fact that 36.4% of the respondents indicated that goats and sheep are more useful (Figure 2). The results of the survey also showed that almost every household interviewed owned goats and sheep. The relative importance of livestock as a source of livelihood is in agreement with previous reports (Guliye *et al.,* 2007 and Noor *et al.,* 2012). There is significant contribution of livestock resources to socio-cultural needs of the households, especially in payment of dowry, compensation for murder/injury, cultural ceremonies and performance of rituals. Generally in South Sudan, livestock are kept to carter for food (milk and meat), cash (progenies and milk sales), recreation, transport and form of wealth, and symbol of social status in the society. The importance of livestock for socio-cultural needs of pastoral communities in Northern Kenya were also described by Guliye *et al.* (2007). In South Sudan, livestock are mainly kept for subsistence but not as market driven enterprise.

3.4.3 Sources of foundation livestock herds and herd structure

The results of the study indicate that majority of the livestock keepers (58.1%) purchased their foundation herd (Table 8). Similar findings were reported in Kenya for camels herd (Noor *et al.,* 2012). Livestock resources being the main source of livelihood amongst the communities, could have motivated the purchase of foundation herd. The high proportion of female animals (Figure 3) is an indication that immature female and male animals were sold to generate income to carter for household needs and other socio-cultural transections. According to the survey, almost all respondents owned livestock mainly sheep and goats. Some respondents reported they keep livestock which they did not own. This is a normal practice in the country where keeping of someone else's herd is as job opportunity, and the caretaker is paid for in cash or in kind (given animals). Majority of the respondents (95%) were affected by loss of livestock during dry season, aggravated by the scarcity of pastures and water. The long distance animals have to walk in search of pastures and water and in the process, they get lost, particularly the goats which tend to browse on the trees.

3.4.4 Livestock management systems and types of land tenure

In the present study, peri-urban livestock production system is predominantly practiced by the livestock owners as compared to pastoral system. The former is mainly practiced by the small scale farmers for subsistence, while the latter is mostly practiced by the pastoral communities who keep large number of livestock for livelihood and social prestige. The respondents indicated that peri-urban system is suitable to urban conditions. Others indicated adoption of the system was due to the influence of extension officers. Majority of the respondents (Figure 5) indicated that keeping livestock around urban centers is necessary to sustain easy access to urban social amenities such as schools, hospitals, infrastructure, business opportunities, etc. Others indicated easy access to urban market for livestock and livestock products and improved security (Figure 5). In South Sudan, there is a high influx of people from rural areas to urban centers, either attracted by the social services or due to rampant insecurity. Moreover, the policy of the government of the Republic of South Sudan to create towns in rural areas to provide adequate basic services to the people may have also contributed to rural-urban migration. Unfortunately, this policy is yet to be fully realized. In most countries, land tenure falls under communally owned land, government owned land, individual owned land and land leased from others. In this study, communally owned land provided significant areas for the grazing of livestock (Figure 6). This is supported by the interim constitution of the Republic of South Sudan which states that land belongs to the community and is not a property of any government (States and National Governments). The actual land owned by the government directly in the study areas is minimal, representing less than 1% of total land, with most of the land being owned by the community (Figure 6). However, government has an upper hand in appropriating the land and thus it controls a small part of the national land (Figure 6).

3.4.5 Indigenous browse trees fed on by ruminant livestock

The important indigenous browse plants predominantly fed on by ruminant livestock in CES are presented in Table 9. The results indicate browse trees are important livestock feed resource which is in agreement with previous findings by (Roothaert *et al.,* 1997; Drechsel and zech, 1998; Mitra and Mitra, 2000; Petit and Diallo, 2001; Elseed *et al.,* 2002; Shelton, 2004; Ansah and Nagbila, 2011; Noor *et al.,* 2012; Gaiballh and Lee, 2012; Belete *et al.,* 2012). The results of this survey show only the most common browses in the three study locations. The results also indicate that almost all ruminant livestock utilized these browse trees. These findings collaborated with those of Gaiballa and Lee (2012) and Ansah and Nagbila (2011), who reported that both leaves and pods are used by various kinds of livestock and wildlife.

The respondents listed forages predominantly browsed by livestock in both wet and dry seasons (Table 10). Almost the same trees were indicated in both seasons, however, in this regard emphasis were made on dry season browses. Some browses shown in this study were also reported by Gaiballa and Lee (2012) as important browses in Western Bahr El Ghazal State of South Sudan. This findings indicate that potential browses that could be used as livestock feed are common and abundant in the study areas. In the current study, the parts of tree browses being utilized by the livestock suggest these trees are important forage resource. These results agree with Le Hourou (1980) who explained that, the idea of browse is complex depending on the plant species, animal species, forage availability and accessibility and the nutritional status of the animals. The respondents surveyed reported that *Ziziphus spina-christi, Acacia nilotica, Combretum adenogonium, Sclerocarya birrea, Balanite aegyptiaca, Afzelia Africana and Tamarindus indica* are the most common browses for livestock. Respondent's knowledge on the use of browse trees in this study agree with Gaiballa and Lee (2012) who reported on importance and utilization of indigenous browse species. These findings were similar to those of Smith (1986) on use of browse trees and shrubs in tropical Africa and Giffard (1971) who reported the important browse species in the humid tropical West African zone.

These results indicate most of the trees and shrubs in CES are reliable sources of feed for livestock during the dry season. The diversity of the browse species reported in this study are similar to those reported by Wicken (1980) who estimated that the flora of tropical Africa contains more than

7,000 species of trees and shrubs, of which at least 75% are browsed to a greater or lesser extent. In this study, the respondents indicated that browse species such as *Acacia, Combretum, Ziziphus, Sclerocarya and Balanites* are valuable because of their ability to produce green leaves in the dry season for livestock feeding.

3.4.6 Important feed resources for livestock and coping strategies

The present survey where native grasses, native browses and crop residues are important forage resources for livestock in CES (Figure 7) agree with the findings of Noor *et al.* (2012) on camels forages in northern Kenya. Browse trees are important livestock feed during dry season (Belete *et al.,* 2012; Abule, 2003, and Teferi, 2006). The current study indicate that grasses, browses (trees and shrubs) and crop residues are the main sources of forage for livestock feeding. The vegetation of the area is savannah grassland with acacia trees dominating areas of low rainfall, and perennial grasses and woodlands in areas with higher rainfall (Equatoria region). These savannas provide animals with sufficient grazing. Rangeland production is seasonal with the beginning of rainy season in April. The majority of the herbaceous plants are annual, where composition and growth is affected by the amount of rainfall. Most trees and shrubs are deciduous but characterized by longer leaf production cycles than the herbaceous plants. The woody fodders are diversified and have various forage components such as leaves (green and dry), pods, fruits and flowers that have longer period of availability. As more land is being cultivated for food production, crop residues have increased and have become an important source of feed resource for livestock. However, their availability depends on the proportion of crop land cultivated and the yield of plant parts. All the crop residues are grazed by the livestock in the field. The use of cultivated forages, non-traditional feed resources and commercially produced feeds is not practiced in CES, similar to previous findings reported by Baars (2000) and Noor *et al.* (2012).

In this survey, respondents indicated that there is severe feed shortage during drought period and that they moved their livestock for longer distance in search of pastures. However, they reported moderate shortage during dry season. This is true because in dry season, the deciduous trees which some of which are ever green are capable of providing feed (leaves, pods and fruits) for livestock, especially for the browsers (goats). The respondents reported some strategies used to overcome feed shortage. The majority indicate prolonging daily grazing time (releasing animals earlier for grazing and returning them late in the evening) and splitting the herd for preferential feeding as the main coping strategies to feed shortage. This is done to reduce competition and allow the disadvantaged animals (small/weak) to graze. Similar strategies to mitigate inadequate feed supply in dry and drought periods have also been reported in Northern Kenya (Noor, 1999; Farah *et al.,* 2004 and Noor *et al.,* 2012). These strategies are also commonly practiced by livestock keepers in CES of South Sudan.

3.5 Conclusion

The study revealed that majority of the livestock owners are elderly and therefore knowledgeable about the various browse resources available in the study counties. This study indicated that there are diverse types of trees and shrubs in Central Equatoria State that are important browses for livestock. The results also show that livestock keepers in the region have indigenous knowledge on utilization of different tree parts by different animal species. The browse fodders play an important role as feed, contributing significant feed resources for livestock particularly as dry season feed.

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CHAPTER FOUR

Nutrient composition of selected indigenous tree browses in South Sudan

Abstract

Indigenous browse tree leaves from *Acacia nilotica, Balanites aegyptiaca, Combretum adenogonium, Sclerocarya birrea and Ziziphus spina-christi* were evaluated for nutritive potential (Chemical composition and mineral profile). All variables determined varied significantly ($P < 0.05$) between the tree browses. *Combretum adenogonium* and *Z. spina-christi* had the highest CP values. *Cumbretum adenogonium* had high CF, *B. aegyptiaca* had high NDF and ADF as well as *S. birrea* also had high ADF. The browse species had phenolic and tannin contents higher than 50 g/kg DM, the maximum tolerable limit in ruminant diets, except *B. aegyptiaca* and *Z. spina-christi* which had significantly ($P < 0.05$) lower total extractable phenols (TEP). *Balanites aegyptiaca* had ($P < 0.05$) lower total extractable tannins (TET) while *C. adenogonium* and *B. aegyptiaca* had significantly ($P < 0.05$) lower total condensed tannins (TCT). The macro and micro elements differed significantly ($P < 0.05$) among the browse tree species. Based on nutrient composition, it is concluded that *C. adenogonium* and *Z. spina-christi* had the best nutritive potential as dietary sources to supplement low quality forages fed to ruminants.

Key words: browses, dietary sources, dry season, livestock, nutritive value, South Sudan.

4.1 Introduction

Livestock is an important source of livelihood for people in South Sudan. Feedstuff of high nutritive value promote high levels of production. Browse leaves form a natural part of the diet for ruminant livestock species and thus have been traditionally used as sources of feed for livestock in Asia, Africa and the pacific (Le Houreou, 1980). Browse trees and shrubs provide nutrition to ruminant livestock especially in the dry season or during drought period when both quantity and quality of grasses decrease (Mogotsi *et al.,* 2015). The browses may be used either as a complete feed or as a supplement to other low quality forages. Browse trees and shrubs possess the desirable agronomic characteristics and high nutritive value to qualify as forage (Norton, 1994). The nutritive value of a feed is determined by its ability to provide necessary nutrients for animal maintenance, growth, production and reproduction. However, in some tree species, there are anti-nutritive factors that may limit it use by livestock. Chemical composition of the feed alone is an inadequate indicator of nutritive value as there is variability in nutrients available. Modern concepts of feed evaluation require that quality be assessed in terms of the capacity of the feed to supply nutrients in proportions to meet particular productive functions (Leng, 1986). Although proximate analysis is a useful measure of nutritive content of forages, analysis based on detergent extraction (NDF, ADF and ADL) are more useful (Gohl, 1981). Despite existence of a wide range of browses in the Republic of South Sudan, there is scanty information available on their nutritive value and animal performance. Therefore, the aim of the current study was to determine the chemical composition and the anti-nutritive component of selected indigenous tree browses native to Central Equatoria State of South Sudan.

4.2 Materials and methods

4.2.1 Selection of Samples

Samples from top 5 indigenous tree species commonly browsed by ruminant livestock in the dry season were selected for analysis. The selected species were; *Acacia nilotica, Balanites aegyptiaca, Combretum adenogonium, Sclerocarya birrea* and *Ziziphus spina-christi.* Selection of the 5 browses was based on the recommendations of a field survey involving livestock owners in the State which identified the most common and preferred browses by the livestock. Sampling was done during the dry season (December – March), because this is the time of the year when browse species are important for grazing. The browses ranked as first and second on the basis of high crude protein and low tannins (anti-nutritive) content upon proximate chemical analysis and *in vitro* digestibility, were further evaluated for feeding trials.

4.2.2 Collection and preparation of the samples

Leaves of the most preferred indigenous tree browses were obtained by hand plucking/clipping between December to March in three purposively selected counties of Juba, Yei and Kajo-keji in CES. Samples of the same tree species were collected from different parts of the selected area. The leaf samples collected were allowed to dry for seven days in the shade to avoid leaf shuttering and wastage. Thereafter, the leaves from same tree species were ground to pass through a 1mm screen and packaged in 1kg plastic bags for analysis.

4.2.3 Chemical Analysis of the samples

The analysis of the samples for proximate composition was done at the Animal Nutrition Laboratory of the Department of Animal Sciences, Egerton University, Kenya. Ground leaf samples of the selected browses were analysed for proximate composition: dry matter (DM), crude protein (CP), ether extracts (EE), and ash, according to the standard methods of AOAC (1990). The fibre component was analyzed for Neutral detergent Fibre (NDF), acid detergent Fibre (ADF) and acid detergent lignin (ADL) according to the method of Van Soest *et al.* (1991). Mineral analyses were carried out using atomic absorption spectrophotometer (AAS) at Kenya Agricultural and Livestock Research Organization (KALRO), Njoro, Kenya. The Macro elements determined were: Calcium (Ca), Phosphorous (P), Sodium (Na), Potassium (K), and Magnesium (Mg); whereas the Micro elements were: Copper (Cu), Zinc (Zn), Iron (Fe), Cobalt (Co) and Manganese (Mn).

Phenolic compounds were extracted following the procedures described by Makkar (2003). Total extractable phenolics (TEP) were determined according to the method of Julkunen-Tiitto (1985) using the Folin Ciocalteu reagent and tannic acid as standard. Total extractable tannins (TET) were determined by the Follins-Dennis spectrophotometric method (Pearson, 1976). In summary, Five milliliters (5ml) of the extracted supernatant was measured into 50ml test tube and diluted with 35ml of distilled water. Standard tannin solution (tannic acid) 5ml and 5ml of distilled water were measured into separate test tube diluted with 35ml distilled water to serve as standard and blank. Then, Follin-Dennis reagent 1ml was added followed by 2.5ml of sodium carbonate solution. The content of the tubes was made up to the mark and incubated for 90 minutes at 37^{o}C. Thereafter, the absorbance was read at 760nm with the reagent blank at zero. The amount of TET was calculated using the formula below:

Total extractable tannin (TET) % $= \frac{100}{1} \times \frac{Au}{As} \times c \times \frac{Vf}{Va} \times DF$

Where; Va = weight of the test sample

Au = Absorbance of the test sample

As = Absorbance of the standard tannin solution

c = concentration of standard mg/ml.

vf = Volume of the extract analysed, df = Dilution factor where applicable.

Total Condensed tannins (TCT) was measured using the butanol-HCl assay (Porter *et al.,* 1986), with the modifications by Makkar (2003) as described by Iqbal *et al.* (2011). Half a ml (0.5ml) of the extract diluted with 70% acetone was measured into glass test tube, 3ml of the butanol-Hcl and 0.1ml of the Ferric Sulphate solution was added to the tubes. The tubes were vortexed and placed on water bath at 60-70^{o}C for 50 minutes then cooled and absorbance recorded at 550 nm. The absorbance of the unheated tubes (blank) was subtracted from the absorbance of the heated tubes. Therefore, TCT (%DM) were calculated as follows:

Total Condensed tannins (TCT) % = A 550nm x 78.26 x DF/sample DM%.

Where; A550nm = absorbance of the sample measured, DF = Dilution factor where applicable. All chemical analyses were carried out in triplicate.

4.2.4 Statistical analysis

The results of the proximate composition, fibre, mineral and anti-nutritive composition were subjected to analysis of variance (ANOVA) using General Linear Model Procedures (proc glm) of statistical package of SAS (2002, version 9.0). All analysis were based on general statistical model:

$Y_{ij} = \mu + S_i + S_e$

Where, Y_{ij} = the general observation on all variables

μ = the overall mean due to all observations

S_i = the effect of i^{th} browse species, S_e = the standard error of means.

Significant means were separated using least significant difference (LSD) test.

4.3 Results

4.3.1 Chemical composition

Results of the chemical compositions of the tree browses are presented in Table 11. *Acacia nilotica, B. aegyptiaca and C. adenogonium* had relatively high ($P < 0.05$) dry matter (DM) content than *Z. spina-christi and S. birrea*, respectively. The OM content of *B. aegyptiaca* is significantly ($P < 0.05$) higher than C. adenogonium, *Z. spina-christi*, *A. nilotica* and *S. birrea* (Table 11). *Cumbretum adenogonium and Z. spina-christi* had high CP content which was significantly higher ($P < 0.05$) than *A. nilotica* and *S. birrea* but not significantly different ($p < 0.05$) from *B. aegyptiaca*. *Balanites aegyptiaca* and *C. adenogonium* had relatively high CF content. *Ziziphus spina-christi* had moderate; and *A. nilotica* and *S. birrea* had low CF. Ether Extract content of the browses ranged from 28.7 to 47.6 g/kg DM in *B. aegyptiaca* and *C. adenogonium*, respectively. The later had significantly ($P < 0.05$) higher EE content than *Z. spina-christi, S. birrea, A. nilotica* and *B. aegyptiaca* (Table 11). Ash content of the browses studied were significantly ($P < 0.05$) different. *Balanites aegyptiaca* and *S. birrea* had high NDF, ADL and ADF, respectively. All the browse species evaluated had low fiber fractions indicated by lower NDF values of less than 500 g/kg DM.

Table 11. Chemical composition (g/kg DM) of 5 selected indigenous tree species browsed by livestock in South Sudan

Browse species	DM	OM	CP	CF	EE	Ash	NDF	ADF	ADL	Rank*
A. nilotica	931^{d}	638^{b}	157^{b}	117^{a}	29.3^{a}	55.5^{a}	154^{a}	143^{a}	85.4^{b}	5
B. aegyptiaca	931^{d}	741^{d}	172^{c}	202^{c}	28.7^{a}	123^{e}	319^{d}	239^{d}	164^{d}	3
C. adenogonium	918^{c}	642^{b}	201^{d}	133^{b}	37.1^{c}	90.3^{d}	210^{c}	194^{c}	57.2^{a}	1
S. birrea	909^{a}	612^{a}	120^{a}	109^{a}	31.2^{b}	80.5^{c}	209^{b}	138^{a}	99.9^{c}	4
Z. spina-christi	929^{b}	696^{c}	200^{d}	204^{c}	47.6^{d}	62.5^{b}	210^{b}	172^{b}	80.1^{b}	2
Overall means	924	666	170	153	35	82	197	207	99.0	
SEM	0.3	1.8	1.7	1.2	0.4	0.3	0.4	3.0	0.5	

$^{a, b, c, d,}$ Means with different superscripts in the same column are significantly different ($P < 0.05$).
*Ranking based on crude protein content

4.3.2 Phenolic content

Results of phenolic and tannin contents are presented in Table 12. Browse tree leaves had low phenolic and tannin contents whereas, *A. nilotica* and *S. birrea* had the highest ($P < 0.05$) values for TEP, TET and TCT. *Balanite aegyptiaca* had significantly ($P < 0.05$) lower phenolic and tannin contents compared to other browses, while *C. adenogonium* had ($P < 0.05$) lowest TCT (4.2 mg/g DM) (Table 12).

Table 12. Total extractable phenolics (TEP), total extractable tannins (TET) and total condensed tannins (TCT) (mg/g DM) in selected indigenous tree species browsed by ruminant livestock in South Sudan

Browse species	TEP	TET	TCT
Acacia nilotica	85.4[d]	79.6[c]	19.0[d]
Balanites aegyptiaca	51.7[a]	25.6[a]	8.7[b]
Combretum adenogonium	76.1[c]	71.9[b]	4.2[a]
Sclerocarya birrea	84.7[d]	75.2[b]	19.9[d]
Ziziphus spina-christi	72.0[b]	42.1[b]	15.5[c]
Overall means	73.9	58.8	13.4
SEM	0.3	0.2	0.1

[a, b, c, d,] Means with different superscripts in the same column differ significantly at $P < 0.05$

4.3.3 Mineral composition

The mineral composition of the browse leaves are presented in Table 13. Most of the browse tree species had relatively high mineral contents. *Ziziphus spina-christi* had the highest ($P < 0.05$) level of Ca. *Cumbretum adenogonium*, *A. nilotica* and *B. aegyptiaca* had ($P < 0.05$) high composition for P, Na, K and Mg, respectively compared to other browse species. On the other hand, *S. birrea* and *Z. spina-christi* had ($P < 0.05$) lower levels of Ca, P and K. Micro elements content ranged from 4.96 to 2701 mg/kg DM. Higher levels of micro elements were found in all the browse species. Co had high mean (2701 mg/kg DM) compared to other micro elements.

Table 13. Macro and trace elements in selected indigenous tree species browsed by ruminant livestock in South Sudan

Browse species	Major elements, g/kg DM					Trace elements, mg/kgDM				
	Ca	P	Na	K	Mg	Cu	Zn	Fe	Co	Mn
A. nilotica	15.1[b]	1.7[a]	9.8[d]	5.9[a]	3.2[b]	95.9[c]	96.2[c]	306[e]	274[c]	5.3[d]
B. aegyptiaca	18.8[c]	1.8[a]	9.5[b]	18.3[e]	8.1[e]	99.9[d]	99.6[d]	194[d]	217[a]	1.7[b]
C. adenogonium	15.9[b]	3.9[b]	9.8[c]	16.1[d]	6.3[d]	133[e]	133[e]	28.1[a]	301[d]	4.2[c]
S. birrea	6.2[a]	1.9[a]	9.8[d]	6.3[b]	3.9[c]	68.8[a]	68.8[a]	86.4[b]	320[e]	1.3[a]
Z. spina-christi	21.8[d]	2.1[a]	8.9[a]	14.7[c]	2.8[a]	81.7[b]	80.7[b]	120[c]	238[b]	12.3[e]
Overall means	15.6	2.3	9.6	12.3	4.9	95.9	95.7	146.8	2701	4.9
SEM	0.4	0.3	0.3	0.1	0.3	0.4	1.1	0.6	31.2	0.2

[a, b, c, d, e] Means with different superscripts in the same column differ significantly at $P < 0.05$

4.4 Discussion

4.4.1 Proximate and fibre composition

The proximate composition in terms of CP, OM, DM, fibre and lignin contents of the browses in the present study are highly variable. The high CP and lower fibre composition indicate most of these browses are potential nitrogen supplements for ruminants feeding on low quality roughage. Inclusion of browse leaves in the diets could overcome nitrogen deficiency and improve on the utilization of low quality feed resources which usually have lower CP contents (30 – 50 g/kg DM) (Leng, 1990 and Rubanza *et al.,* 2003). The CP reported in this study is higher than the minimum requirement of 80 g/kg DM needed for optimal rumen microbial function (Annison and Bryden, 1998). High CP content of browse tree leaves observed in the current study is consistent with values reported elsewhere for browse species (Abdulrazak *et al.,* 1997; Ben salem *et al.,* 1997; Abdulrazak *et al.,* 2000 and 2001; Nantoume *et al.,* 2001; Rubanza *et al.,* 2003; Ondiek *et al.,* 2010; Belete *et al.,* 2012 and Dambe *et al.,* 2015). In this study, *Z. spina-christi* had high CP values (201 g/kg DM). However, Gaiballa and Lee (2012) reported low values of CP and high levels of CF for some browse species (*Balanites aegyptiaca, Grewia mollis* and *strychnos spinosa*) from South Sudan. The role of browses as nitrogen sources for ruminants, especially during dry season, in the tropics where other protein sources are not available or expensive. The browse forages show low to moderate fibre and lignin content (Table 11) which is a positive attribute as the feed intake and digestibility are dependent on fibre particularly, the NDF and lignin. The results of the fibre fraction agree with those reported by Bakshis and Wadhwa (2004). The fibre content of browse species has been shown to be more digestible than that of grasses and crop residues (El Hassan *et al.,* 2000). This could be due to supply of nitrogen from the browse leaves that provide the microorganisms in the rumen with degradable nitrogen.

4.4.2 Phenolic content

In the current study, all browse trees except *B. aegyptiaca* and *Z. spina-christi* had high phenolic and tannin contents greater than the 50 mg/g DM reported to be the minimum beneficial level in ruminants (Mangan, 1988). However, *C. adenogonium* had the lowest TCT (4.2 mg/g DM) content. *Acacia nilotica* and *S. birrea* had the highest phenolic and tannin concentrations (Table 12). Higher concentrations of phenolic and condensed tannins were also reported in other studies on browse species by Reed (1986), Abdulrazak *et al.* (2000a,b), Elseed *et al.* (2002), Rubanza *et al.* (2003), Osuga *et al.* (2006) and Ondiek *et al.* (2010). Higher levels of phenolic and tannins in browses tend to lower feed digestibility and decrease nutritive values through decreased digestibility and nutrient utilization (Makkar and Becker, 1996; Abdulrazak *et al.,* 2000 and Rubanza *et al.,* 2003). Several factors are associated with high phenolic and tannin concentrations in browses and these include high environmental temperatures, drought and defensive mechanism against invading pathogens (Mangan, 1988 and Rubanza *et al.,* 2003). Phenolic and tannin contents in browse species may vary due to different assays used and the standards used in samples analysis (Makkar and Becker, 1993). On the other hand, differences in phenolic and tannin levels may be due to the stage of plant maturity, season of harvesting of browse material and the location of growth (Woodward and Reed, 1989; Makkar and Becker, 1998; Abdulrazak *et al.,* 2001 and Rubanza *et al.,* 2003).

4.4.3 Mineral composition of the selected indigenous browse species

Mineral composition of the browse tree species in the current study is high. All browse species except *S. birrea* had high levels of Ca (Table 13). These values agree with those reported in the same and other browse species (Abdulrazak *et al.,* 2000; Aganga *et al.,* 2000; Elseed *et al.,* 2002 and Ondiek *et al.,* 2010). The P levels corresponded well with the values reported for Balanites and Ziziphus browses (Ondiek *et al.,* 2010). The Ca levels in the browse leaves studied except *S.*

birrea were relatively high exceeding the recommended level (11 g/kg DM) for lactating ewes (NRC, 1985), while P (7.7 g/kg DM) is lower for lactating ewes. Elis (1982), Elseed *et al.* (2002) and Ondiek *et al.* (2010) reported similar lower P values in different browses. The concentrations of Na and K were high in all the browse species. Browse trees contain high levels of Mg between 2.8 to 8.07 g/kg DM. The browse tree leaves studied currently indicate adequate levels for ruminant requirements. The concentrations of macro elements were higher compared to requirements suggested for growth (2.4 – 10.8 g/kg DM Ca), pregnancy (1.4 – 3.5 g/kg DM Ca) and lactation (2.8 – 5.3 g/kg DM Ca) (ARC, 1980 and Meschy, 2000) indicating that browse diets can sustain the animals. Also P, Mg, Na and K values in this study are higher compared to recommended requirements as suggested by Minson (1990), Underwood and Suttle (1999); and NRC (2001). The results on macro elements suggest that animals feeding on natural fodders in the area of study may not require mineral supplementation. The micro elements in this study indicate higher levels with the exception of Mn which was lower (Table 13). Higher values were observed for Cu, Zn, Fe, Co and Mn. These results are comparable to those reported by Rubanza *et al.* (2003) and Ondiek *et al.* (2010). The concentration of micro elements were higher than the amounts required for growth, pregnancy and lactation as suggested by ARC (1980), Minson (1990), Underwood and Suttle (1999), Meschy (2000) and NRC (2001); except for Mn which may need to be supplemented because of the lower values than that recommended for growth, pregnancy and lactation.

4.5 Conclusion

Indigenous tree species in Central Equatoria State have nutritive potential as indicated by high crude protein and low fibre contents. However, most of the browses contained high levels of phenolic and tannins greater than 50 g/kg DM, the maximum tolerable limit by ruminants. These higher levels could decrease the nutritive potential of these browses due to effect on taste and digestibility. Condensed tannins also bind enzymes and nutrients making them unavailable to the host animal and higher fecal losses of the nutrients such as protein. The results of the study indicate that the browses would form adequate sources of mineral supplements to ruminant livestock. Browse species had mineral levels higher than the dietary requirements for ruminant livestock. However, excessive levels of Co could be harmful to livestock depending on the inclusion levels. These findings suggest the need for further investigation on the practical feeding trials to guarantee adequate nutritional evaluation on these browse species.

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CHAPTER FIVE

Evaluation of *in vitro* dry matter digestibility of selected indigenous tree browses as feed for ruminant livestock in South Sudan

Abstract

Browse tree leaves from *Acacia nilotica, Balanites aegyptiaca, Combretum adenogonium, Sclerocrya birrea* and *Ziziphus spina-christi* were evaluated for their *in vitro* gas production and potential degradability. Browse species were collected from a field survey conducted in purposively selected counties. All the parameters studied varied significantly (P < 0.05). Means for *in vitro* gas production incubation time ranged from 30.6 to 45 ml/kg DM for 3 and 96 hr, respectively. *Balanite aegyptiaca, C. adenogonium* and *Z. spina-christi* at 48 hr 72 hr and 96 hr had high gas production potential compared to *A. nilotica* and *S. birrea*. *In vitro* OM degradability was significantly (P < 0.05) different between the browse species. In the study, *C. adenogonium* and *Z. spina-christi* had the highest (P < 0.05) degradability while *A. nilotica* and *S. birrea* had (P < 0.05) lower degradability values. Browse species ranking in order of degradability is: *Z. spina-christi* > *C. adenogonium* > B. *aegyptiaca* > *S. birrea* > *A. nilotica*. The estimated metabolizable energy (EME) values were relatively similar but *B. aegyptiaca, C. adenogonium* and *Z. spina-christi* had higher (P < 0.05) values compared to *A. nilotica and S. birrea*. Browse ranking on the basis of estimated metabolization energy (EME) is: *C. adenogonium* > *Z. spina-christi* > *B. aegyptiaca* > *A. nilotica* > *S. birrea*. These browse species have the potential to supplement ruminants feeding on low quality forages with highly degradable feed resources that could provide rumen degradable protein. Further studies are required to evaluate these browse species for intake and growth performance in ruminant livestock.

Key words: browse species, gas production, metabolizable energy, organic matter degradability, Republic of South Sudan.

5.1 Introduction

Leaves of tree browses play a critical role in supplementing low qualify feed with nitrogen, especially during dry season. Browse leaves are an important component of grazing goats and sheep (Papachristou and Nasis, 1996). They also play an important role in the nutrition of grazing livestock in areas with poor quality forage (Meuret *et al.,* 1990). However, utilization of tree leaves depend on the tannins content. Although tree leaves are important forage for ruminant livestock, there is limited information on the nutritive value of the indigenous tree browses in Central Equatoria State of the Republic of South Sudan. Therefore, the objective of the current study was to evaluate the nutritive value of the indigenous tree browses based on *in vitro* dry matter digestibility and the estimated Metabolizable energy.

5.2 Materials and methods

5.2.1 Selection of Samples

Samples for the study comprised of 5 indigenous tree species commonly browsed by ruminant livestock in Central Equatoria State of South Sudan. The samples were analysed for *in vitro* gas production, organic matter degradability and metabolizable energy. The selected species are; *Acacia nilotica, Balanites aegyptiaca, Combretum adenogonium, Sclerocarya birrea* and *Ziziphus spina-christi.* The ground leaves of the selected tree browses were packaged in 1kg plastic bags and transported to Animal Nutrition laboratory of the Department of Animal Sciences, Egerton University, Kenya, for analysis. The samples were used in determination of *in vitro* dry matter digestibility, gas production and the estimation of Metabolizable energy.

5.2.2 Rumen fluid collection and incubation

The milled dried leaves of browses was evaluated for *in vitro* digestibility. Rumen fluid was obtained from two Friesian fistulated steers in Tatton Agriculture Park (TAP) of Egerton University. The animals were fed on a basal diet of Rhodes grass hay *ad libitum* and given free access to clean drinking water and mineral/vitamin block. A suction bottle (500 ml) was used to collect rumen fluid from various parts of the rumen of each steer. Samples of rumen fluid was withdrawn before morning feeding, transferred into thermos flasks to keep the rumen fluid temperature warm and taken immediately to the laboratory and strained through three layers of cheesecloth to remove fibrous food particles and then kept at 39°C under a constant flow of carbon dioxide (CO_2) to maintain anaerobic conditions. Buffer and minerals solution were prepared as described by Menke and Steingass (1988) and used by Guliye *et al.* (2005). Digestion medium was prepared by mixing 500 ml of distilled water, 0.1 ml micro mineral solution, 200 ml buffer solution, 200 ml macro mineral solution, and 1 ml Resazurine solution (Kamalak *et al.,* 2005). CO_2 gas was bubbled through the solution until the colour changed to pink/purple. Then, 1 ml of ruminal fluid was added to 2 ml of buffer and mineral solution to make diluted ruminal fluid. Thirty (30) ml of the diluted ruminal fluid were injected into triplicate syringes with 200 mg of each of milled browse leaf samples. The syringes were incubated in a water bath at 39°C for 96 hr. Syringes with only 30 ml of diluted ruminal fluid only were incubated to correct for endogenous gas production. The syringes were incubated and the volume of gas produced was recorded before incubation (0) and thereafter 3, 6, 12, 24, 48, 72 and 96 hr of incubation. Total gas production values were corrected for blank incubation.

5.2.3 *In vitro* digestibility

The *in vitro* digestibility was determined using the technique of Menke *et al.* (1979) as described by Abdulrazak and Fujihara (1999) and used by Ondiek (2012). The obtained gas values were fitted into the equation: $Y = a + b\,(1 - e^{-ct})$ of Ørskov and McDonald (1979); Where,

Y = the gas produced at the time (t)

a = the volume of gas produced/ml at time t

b = the potential gas production (ml)

c = the gas production rate constant

a + b = the potential gas production (ml)

t = incubation time (hr)

In vitro organic matter digestibility was determined from the equation of Menke *et al.* (1979), and the metabolisable energy (ME; MJ/kg DM) calculated using equation of Menke *et al.* (1979) as follows: ME (MJ/kg DM) = 2.20 + 0.136GP + 0.057CP where, GP is 24 hr net gas production (ml/200mg) and CP is Crude protein (%).

5.2.4 Statistical analysis

Results of *in vitro* gas production and OM degradability characteristics were subjected to analysis of variance (ANOVA) using General Linear Model Procedures (proc glm) of statistical package of SAS (2002, version 9.0). All analyses were based on the general statistical model:

$Y_{ij} = \mu + S_i + S_e$

Where, Y_{ij} = the general observation on the tested variables

μ = the overall mean due to the observations

S_i = the effect of i^{th} browse species

S_e = the standard error of means.

Significant means were separated using least significant difference (LSD) test.

5.3 Results

5.3.1 *In vitro* gas production characteristics

The *in vitro* gas production characteristics of the browse species are presented in Table 14. Gas production potential was significantly ($P < 0.05$) different among browse species at various reading interval. Potential cumulative gas production was lower in *A. nilotica* and *S. birrea*; intermediate in *C. adenogonium* and higher in *B. aegyptiaca* and *Z. spina-christi*. Means for *in vitro* gas production characteristics in different incubation time interval ranged from 30.6 to 45.0 ml/200 mg DM. Organic matter degradability characteristics between the browses are presented in Table 15. Values for a, b, (a+b) and c are significantly ($P < 0.05$) different between the browse trees in the study. The percentage degradability characteristics of the browse leaves ranged from 0.00 to 1.01, 0.54 to 3.86, 1.27 to 4.61 and 0.07 to 9.54% in *B. aegyptiaca* and *S. birrea, S. birrea* and *Z. spina-christi*, *A. nilotica* and *Z. spina-christi*; and *Z. spina-christi, C. adenogonium* and *B. aegyptiaca* for a, b, (a+b) and c values, respectively (Table 15).

Degradability for *A. nilotica* and *S. birrea* was lower; *B. aegyptiaca* and *C. adenogonium* intermediate degradability, while *Z. spina-christi* had the highest although not significantly ($P > 0.05$) different from *B. aegyptiaca* and *C. adenogonium. Balanites aegyptiaca* had significantly ($P < 0.05$) higher rate constant (c) compared to other browse species in this study. The browse trees under investigation can be categorized into three groups of low degradable (*A. nilotica* and *S. birrea*), moderate to high degradable (*B. aegyptiaca* and *C. adenogonium*) and highly degradable (*Z. spina-christi*). The estimated metabolizable energy (ME, MJ/kg DM) values of the browse species were relatively similar. However, *A. nilotica* and *S. birrea* had significantly ($P < 0.05$) lower ME compared to *B. aegyptiaca, C. adenogonium* and *Z. spina-christi* which are not significantly ($P > 0.05$) different from one another (Table 15).

Table 14. Cumulative *in vitro* gas production (ml) for selected tree browse leaves in South Sudan

Browse species	Incubation time (hr)						
	3	6	12	24	48	72	96
A. Nilotica	29.0^{a}	30.0^{a}	30.0^{a}	30.5^{a}	31.6^{a}	33.1^{a}	33.3^{a}
B. aegyptiaca	30.0^{b}	32.0^{ab}	35.1^{b}	39.6^{ab}	47.1^{b}	51.6^{b}	53.6^{b}
C. adenogonium	31.0^{c}	32.0^{ab}	34.3^{b}	38.1^{ab}	44.0^{b}	47.1^{b}	49.1^{b}
S. birrea	31.0^{c}	31.0^{b}	33.5^{b}	34.6^{b}	35.6^{a}	36.1^{a}	36.6^{a}
Z. spina-christi	32.0^{d}	32.0^{ab}	34.3^{b}	38.3^{ab}	45.3^{b}	50.0^{b}	52.1^{b}
Overall means	30.6	31.6	33.4	36.2	40.7	43.6	45.0
SEM	0.4	0.9	1.7	3.1	3.9	4.7	4.7

a, b, c, d Means with different superscripts in the same column are significantly different at $P < 0.05$

Table 15. Organic matter degradability characteristics (%) and ME, MJ/kg DM of selected browses

Browse species	OM degradability characteristics					
	a	b	(a+b)	c	RSD	ME
A. nilotica	0.2^{b}	1.1^{b}	1.3^{a}	0.4^{b}	0.7^{a}	3.3^{a}
B. aegyptiaca	0.0^{a}	3.7^{d}	3.7^{c}	9.5^{c}	2.5^{c}	3.9^{b}
C. adenogonium	0.3^{c}	3.3^{c}	3.6^{c}	0.1^{a}	1.8^{b}	3.9^{b}
S. birrea	1.0^{d}	0.5^{a}	1.5^{b}	0.1^{a}	0.5^{a}	3.1^{a}
Z. spina-christi	0.8^{dc}	3.9^{d}	4.7^{d}	0.1^{a}	1.9^{c}	3.9^{b}
Overall means	0.5	2.6	2.8	2.0	1.5	3.6
SEM	0.2	0.5	0.4	0.5	0.5	0.2

a, b, c, d, Means with different superscripts in the same column differ significantly ($P < 0.05$).

5.4 Discussion

The differences in diet degradability observed in the current study could be due to effects of anti-nutritive (phenolic and tannin) substances as well as fibre content in the browse (Mangara *et at.,* 2017). The effect of phenolics and tannins decrease feed digestibility by binding nutrients and making them unavailable for digestion has been reported by other researchers (Makkar *et al.,* 1995; Makkar and Becker, 1996; Abdulrazak *et al.,* 2000; Getachew *et al.,* 2000; Rubanza *et al.,* 2003; Osuga *et al.,* 2006, 2007 and 2008; and Ondiek *et al.,* 2010). Variability of tannins between plant species can be attributed to phenolic type, conformity and reaction mechanisms that result to differential action of anti-nutritive factors (tannins) on degradability (Makkar and Becker, 1993 and Rubanza *et al.,* 2003). Fibre composition (Fonseca *et al.,* 1998; Rubanza *et al.,* 2003); and lignin content (Van soest, 1994) in the feed determines the extent and rate of feed degradability. In the current study, some browse species had high levels of NDF, ADF and ADL that could have resulted in their variations in degradability. *In vitro* gas production potential in this study indicate significant difference between the browses. These results are well collaborated with those reported in previous studies (Abdulrazak *et al.,* 2000; Rubanza *et al.,* 2003; Osuga *et al.,* 2008 and Ondiek *et al.,* 2010).

Blummel and Fennandez-Rivera (2002) reported that gas production is due to fermentation of organic matter in the feed. Therefore, variations in gas production between different browse species could be due to the amount of substrate fermented *in vitro*. In the present study, *B. aegyptiaca*, *C. adenogonium* and *Z. spina-christi* had high gas production than the rest of the browse. This could be due to high organic matter in these browses. Osuga *et al.* (2008) also reported similar findings for browse forages in Kenya. The calculated metabolizable energy (ME) values are lower than those reported by Elis (1982) on some browse species native to South Sudan rangelands. Results of this study indicate that *B. aegyptiaca*, *C. adenogonium* and *Z. spina-christi* are highly degradable and fermentable. However, the most highly degradable browses are *C. adenogonium* and *Z. spina-christi* because they have higher OM degradability characteristics. Therefore, these could serve as good supplements for ruminant livestock especially, during dry season when other quality forages are in short supply and crop residues and other fibrous based roughage are available.

5.5 Conclusion

Tree browse species in Central Equatoria State have the potential as feed for ruminants as shown by high organic matter degradability. High degradability of these browses could increase nitrogen content in the rumen and increase microbial population in the rumen that could digest more of poor quality roughages and also increase microbial crude protein that can be digested and absorbed in the small intestines. This study recommend that *C. adenogonium*, *B. aegyptiaca* and *Z. spina-christi* be used on feeding trials to guarantee the nutritive value of these browses on animal performance.

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CHAPTER SIX

Nutrient utilization and growth performance of cross-bred goats fed *Ziziphus spina-christi* and *Combretum adenogonium* forages, sole and mixture supplemented to Rhodes grass (*Chloris gayana*) hay.

Abstract

Twenty cross-bred goats of both sexes were fed *Combretum adenogonium* and *Ziziphus spina-christi,* singly and in combination as supplement to basal diet of Rhodes grass (*Chloris gayana*) and evaluated for dry matter intake, apparent digestibility, nitrogen utilization and growth performance. Four goats were allocated to each of five dietary treatments in a randomized complete block design. The five dietary treatments (%) comprised of Combretum (C) and Ziziphus (Z). The ratios were: C0Z100, C25Z75, C50Z50, C75Z25 and C100Z0, respectively. Total dry matter intake was not significantly (P > 0.05) different in all the treatment diets, however, feed intake increased with increased inclusion rate of *Ziziphus spina-christi*. Significant difference occurred in nutrient digestibility of all the experimental diets, with C0Z100 showing a significant (P < 0.05) effect of all the nutrients. Animals feeding on C25Z75 had significant (P < 0.05) retention of nitrogen and C75Z25 but with least retained nitrogen. The live weight gain (g/day) was (P < 0.05) high in C0Z100. The least weight gain was observed in C100Z0. The results of this study showed that *Ziziphus spina-christi* leaves were more acceptable and palatable to goats, whether fed singly or combined and supplementing to low quality feed increased dry matter intake, nitrogen utilization and live weight gain, thus can serve as dry season supplements to poor quality forages.

Keywords: Browse forages, cross-bred goats, dry season supplements, feed intake, weight gain

6.1 Introduction

Natural pastures are the main natural diets of ruminant livestock in the tropics. In South Sudan, livestock are significant sources of animal protein for human. Livestock is severely affected by inadequate or unavailability of quality natural pastures particularly during dry season which leads to slow growth rate and low productivity of animals. Many authors have reported the importance of feeding supplements to improve livestock productivity during the dry season (Aregheore *et al.,* 2004; and Mogotsi *et al.,* 2015). Utilization of browse trees and shrubs could be an important strategy to increase the quality and availability of feeds to ruminant livestock owners in the dry season (Sultana *et al.,* 2015). Trees and shrubs have been reported to supply good quality and cheaper source of rumen degradable nitrogen, fermentable energy and micronutrients (Moyo *et al.,* 2012). The multipurpose trees are reliable feed resources of high quality and they can be used to develop sustainable feeding system and increase livestock productivity (Okoli *et al.,* 2003). In many parts of the world, more attention is being given to trees and shrubs to supplement low quality forages for livestock feeding (Okoli *et al.,* 2003). The current study was undertaken to determine nutrient utilization and growth performance of cross-bred goats fed *Ziziphus spina-christi* and *Combretum adenogonium* forages, singly and in various combinations supplemented to basal Rhodes grass (*Chloris gayana*) hay.

6.2 Materials and methods

6.2.1 Experimental site

The study was carried out at Dairy Goat Breeding and Multiplication center, Njoro campus, Tatton Agricultural Park of Egerton University, Kenya, from 4th March to 12th May 2017. The area lies at an altitude of 2238 m above sea level. The mean range of temperature and rainfall were 17^{o}C to 22^{o}C and 900 to 1200 mm, respectively, (EUEMS, 2009).

6.2.2 Feed preparation

Leaf samples of the two best ranked out of five indigenous tree browses on the basis of high CP content and OM degradability were collected from Central Equatoria State of South Sudan. Ranking was determined by adding the powers on each browse score however, CP took precedence as a limiting factor (Table 11). They were collected from three locations/counties within the State. The leaf forages were obtained by hand plucking during the dry season from December to March. The forage was dried in shade for seven days to avoid wastage then ground to pass through a 4 mm screen parked in gunny bags and transported to the experimental site at the Njoro campus of Egerton University, Kenya. Rhodes grass hay was purchased from a commercial farm near the campus and milled to pass through a 4 mm screen and used as basal diet.

6.2.3 Experimental animals and management

Twenty (20) goats of both sexes, aged 6-10 months and weighing 13.5 ± 3 kg were used. The animals were from Tatton Agriculture Park, Egerton University. Animals were fed a basal diet at first for one week for backgrounding, then weighed and live weight listed from the lowest to highest. Animals were allocated per treatments such that all the five diets had animals with mean live weights that were not significantly different. Thereafter, animals were dewormed before commencement of the experiment, with an oral suspension containing 100mg/ml (10%) albendazole® used for the treatment of roundworms, tapeworms and flukes. All the twenty goats were confined in individual cages with raised slats in a house. Each pen was measuring 1 x 1.5 M; and fitted with feed trough and water facility. The goats were routinely sprayed every two weeks using Dominex 100 EC to control external parasite. Ten (10) mls of Dominex was diluted with 20 L of water then sprayed on the animals using hand pump.

6.2.4 Experimental diets, treatment and feeding

Five experimental diets that comprised of *Ziziphus spina-christi* (Z) and *Combretum adenogonium* (C) fodders, fed singly or in combinations (Table 16) and offered on dry matter basis. Goats as natural browsers they browsed on different pastures therefore, mixing the two browses was to determine the synergistic effect of the browse species fed to the goats. The components of the experimental diets were: 100% *Ziziphus spina-christi* + 0% *Combretum adenogonium* (Z100C0), 75% *Ziziphus spina-christi* + 25% *Combretum adenogonium* (Z75C25), 50% *Ziziphus spina-christi* + 50% *Combretum adenogonium* (Z50C50), 25% *Ziziphus spina-christi* + 75% *Combretum adenogonium* (Z25C75) and 0% *Ziziphus spina-christi* + 100% *Combretum adenogonium* (Z0C100). The supplements were thoroughly mixed to minimize animal selection. The goats were fed a basal diet of Rhodes grass hay *ad libitum*. During the feeding trial, all animals had free access to clean drinking water and mineral supplement (Vitaphos Biomin) *ad libitum*. Forty percent (40%) of the browse supplements were fed in two portions preferentially at 0830 and 1600 hr and sixty percent (60%) of the basal diet was made available for the rest of the day to determine intake.

6.2.5 Experimental procedures and design

The animals (four animals per treatment) were randomly allotted to the five experimental treatments in a completely randomized design (CRD). Animals were allocated to individual pens for 14-day acclimatization period then followed by performance trial for 60 days.

Experimental layout

Treatments (T) 5: T1, T2, T3, T4 and T5

Repeats (R) 4: R1, R2, R3 and R4

Experimental units: T x R = 20

T1	T2	T3	T4	T5
R1 (10)	*R1 (15)*	*R1 (4)*	*R1 (17)*	*T1 (5)*
R2 (3)	*R2 (9)*	*R2 (19)*	*R2 (13)*	*T2 (12)*
R3 (14)	*R3 (7)*	*R3 (1)*	*R3 (16)*	*T3 (2)*
R4 (18)	*R4 (6)*	*R4 (20)*	*R4 (8)*	*T4 (11)*

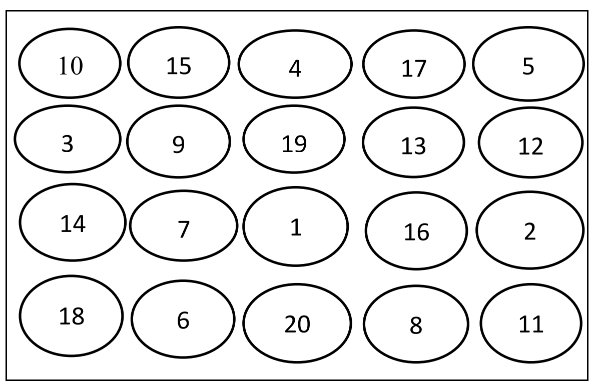

Figure 9. Layout of 20 experimental units (goats) in completely randomized design

Table 16 Dietary composition of the experimental diet

Treatments	Dietary composition			
	Ziziphus Spina-christi	***Combretum adenogonium***	**Supplement total %**	**Basal Diet**
1	0	100	40	*Ad lib*
2	25	75	40	"
3	50	50	40	"
4	75	25	40	"
5	100	0	40	"

6.2.6 Digestibility and Nitrogen balance trials

After sixty days of feeding experiment, the pens were fitted underneath with polythene sheet and 2 mm gauze facility designed for faeces and urine collection. Fifteen (15) goats of both sexes were selected, three (3) from each treatment and used for the determination of digestibility and nitrogen retention for a period of seven (7) days. Similar feeding and management practices were applied to the goats and the facility as in the feeding trial. During the experimental period, daily feed intake was measured. Feed refusals, faeces and urine were collected and weighed every morning. Ten percent of faeces and urine was collected and pooled for each animal daily and kept for later analyses. Nitrogen loss from the urine was prevented by adding 10ml of H_2SO_4 (10%) solution into the urine collection container.

6.2.7 Data collection

During the feeding trial, feed offered and feed refusal were individually collected and daily weighed before morning feeding. Weekly body weight of the animals was measured. The following parameters were then determined: voluntary feed intake (Total feed offered minus total feed refusal), average weight gain (final live weight minus initial live weight); Daily weight gain (average weight gain divided by sixty days experimental period); Feed conversion efficiency (daily dry matter intake divided by daily weight gain); nutrient digestibility (ND) and nitrogen retention (NR).

6.2.8 Chemical analysis

The collected samples of feed offered, refusal and faeces were dried in an oven at 105°C and ground through 1mm for chemical determination, and through 0.5 mm for analysis of phenolic compounds. The nitrogen of the feed and faeces and urine NH_3-N was determined using AOAC (1990). The ash and OM content was determined by the method of Van Soest *et al.* (1991). Apparent nutrient digestibility was determined by difference of the nutrient content in feed and faeces. Nitrogen balance was calculated using the formula: Nitrogen Balance = Nitrogen Intake - (Faecal nitrogen + Urinary Nitrogen).

6.2.9 Statistical analysis

All data collected were subjected to analysis of variance (ANOVA) in a completely randomized design using the General Linear Model Procedures (proc glm) of the Statistical Package of SAS (2002) where, initial live weight was fitted as a covariate in the determination of feed intake and live weight gain. Significant means were separated using Tukey HSD (Tukey Honestly Significant Difference Test) at 5% significance level. The model under completely randomized design was used:

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

Where, Y_{ij} = dependent variables (DMI, AWG, DWG, FCR, ND and NR).

μ= overall mean due to all observations,

T_i = effect of i^{th} treatment diet $\{i = 1,2,3,4,5\}$

E_{ij} = Random error effect.

6.3 Results

6.3.1 Proximate composition of experimental diets

The chemical composition of the experimental diets is shown in Table 17. The composition indicate similar levels of dry matter (DM). Other nutrient components (OM, CP, NDF, ADF and tannins) were highly variable among all the dietary treatments. The crude protein contents of diet 1 and diet 5 were similar than diet 2, diet 3 and diet 4 having the lowest crude protein content. Diets 4 and 5 contain significantly lower amount of total extractable phenols compared to diet 4 that had lower concentration of total tannins. Total condense tannins was significantly lower in diet 1.

Table 17 Chemical composition of experimental diets (g/kgDM)

	D1 C0Z100	D2 C25Z75	D3 C50Z50	D4 C75Z25	D5 C100Z0	SEM
DM	947.1	962.7	947.0	940.4	926.7	1.2
OM	872.2	858.1	870.7	888.2	885.9	2.4
CP	192.7	169.1	170.1	142.7	189.6	0.4
NDF	210.5	234.2	206.0	180.0	210.7	0.8
ADF	191.8	188.0	193.7	155.6	196.4	1.7
TEP	75.6	67.6	59.1	33.2	43.4	0.2
TET	70.6	69.7	62.8	42.7	72.0	0.3
TCT	4.2	16.4	14.7	14.8	15.5	0.1

C = *C. adenogonium, Z = Z. spina-christi*; SEM = Standard Error of Means

6.3.2 Feed intake, nutrient digestibility and nitrogen balance

The feed intake, apparent digestibility and nitrogen retention for the goats are shown in Table 18. Basal diet (Rhodes grass hay) intake in all the experimental diets had no significant ($P > 0.05$) difference but, was lower in C50Z50 combination. Animals feeding on C100Z0 showed a high intake of the basal diet (Rhodes grass). Dry matter intake of the supplement was high ($P < 0.05$) in forage combination of C0Z100, C25Z75 and C50Z50. The intake of the supplement increased significantly ($P < 0.05$) with increasing levels of *Z. spina-christi*. In all the experimental diets, total dry matter intake had no significant ($P > 0.05$) difference though higher intake was observed in C0Z100, C25Z75 and C50Z50. Total intake decreased with increased levels of *C. adenogonium,* when the two browse forages were combined, total dry matter intake was highest in C25Z75.

Apparent digestibility coefficient of the nutrients increased significantly ($P < 0.05$) in C0Z100 than in C25Z75, C50Z50, C75Z25 and C100Z0. The nitrogen intake on dry matter basis was significantly high ($P < 0.05$) in C0Z100 and C100Z0, respectively. Nitrogen loss in faeces was significantly ($P < 0.05$) high in C50Z50, C75Z25 and C100Z0. Animals feeding on C0Z100 significantly ($P < 0.05$) lost more urinal nitrogen than those on the other diets. Animals on C25Z75 retained more nitrogen ($P < 0.05$) at 2.06 gNd^{-1} than animals on other dietary groups (C0Z100, C50Z50, C75Z25 and C100Z0), respectively.

Table 18. Feed intake, digestibility coefficient and nitrogen balance of cross-bred goats

Parameter	Dietary treatments					
	D1	D2	D3	D4	D5	
	C0Z100	C25Z75	C50Z50	C75Z25	C100Z0	SEM
Feed intake (g/day)						
Basal diet	406.3	430.5	374.2	452.1	468.4	57.6
Supplement	232.2^{b}	227.6^{b}	239.1^{b}	120.2^{a}	107.1^{a}	63.6
Total DMI (g/d)	638.5	658.2	613.3	572.2	575.5	89.8
Apparent digestibility coefficient (%)						
Dry matter	62.7^{d}	58.1^{c}	52.5^{a}	51.3^{a}	55.3^{b}	0.6
Organic matter	60.3^{d}	52.5^{bc}	48.5^{b}	47.4^{a}	50.1^{c}	1.0
Crude protein	78.1^{c}	83.9^{c}	51.2^{a}	53.2^{a}	67.7^{b}	4.1
Neutral detergent fibre	54.1^{c}	47.6^{b}	33.3^{a}	34.0^{a}	29.9^{a}	2.6
Acid detergent fibre	57.5^{b}	51.4^{ab}	46.6^{a}	50.6^{ab}	53.3^{ab}	4.4
Nitrogen balance, gNd^{-1}						
Nitrogen intake	3.1^{c}	2.7^{b}	2.7^{b}	2.2^{a}	3.0^{c}	0.1
Nitrogen loss						
Faecal Nitrogen	0.8^{ab}	0.4^{a}	1.1^{b}	1.1^{b}	0.9^{b}	0.2
Urinal nitrogen	0.7^{d}	0.2^{a}	0.4^{cd}	0.3^{c}	0.4^{b}	0.1
Nitrogen Retained	1.6^{bc}	2.1^{c}	1.3^{b}	0.9^{a}	1.6^{bc}	0.2

$^{a, b, c, d,}$ *Means with different superscripts in the same row differ significantly (P < 0.05)*
SEM = Standard Error of Means

6.3.3 Growth performance of cross-bred goats fed forage combinations of *Ziziphus spina-christi* and *Combretum adenogonium* supplemented to Rhodes grass (*Chloris gayana*) hay

The growth performance of the cross-bred goats is shown in Table 20. The results on the goat's performance indicate significant (P < 0.05) dietary effects on growth. All the experimental diets had a positive weight gain, however, higher average gain was observed in C0Z100 which increased linearly with higher proportion of *Ziziphus spina-christi*. Weight gain was significantly (P < 0.05) high in animals feeding on C0Z100. The mixtures C25Z75 and C50Z50 had no (P > 0.05) difference on weight gain. Similar observations were also indicated on C75Z25 and C100Z0, respectively. Lower ($P < 0.05$) weight gain was observed for animals feeding on C75Z25 and C100Z0. There was a significant difference ($P > 0.05$) in feed conversion ratio in animals on the 5 dietary treatments, however, higher amounts of forage had been utilized by animals with higher proportion of *C. adenogonium*. Higher inclusion of *Z. spina-christi* had shown lower Feed conversion ratio.

Initial and final weights of goats per experimental treatment are indicated in Table 19.

Table 19. Initial and final weights of goats per treatment

Treatments	Goats no.	Initial weight	Final weight
Trt 1	10	11.5	15.0
	3	16.5	19.0
	14	12.0	14.5
	18	13.0	15.0
Trt 2	15	15.0	16.0
	9	17.5	19.0
	7	14.0	17.0
	6	13.5	16.0
Trt 3	4	13.0	14.3
	19	8.0	10.0
	1	18.0	19.0
	20	13.0	15.0
Trt 4	17	17.5	19.0
	13	12.0	14.5
	16	9.5	10.2
	8	10.0	11.0
Trt 5	5	8.5	10.0
	12	12.0	13.5
	2	17.5	19.0
	11	16.0	17.5

Table 20. Growth performance of cross-bred goats

Parameter	Dietary treatment					
	D1	D2	D3	D4	D5	
	C0Z100	C25Z75	C50Z50	C75Z25	C100Z0	SEM
Initial wt. (kg)	13.3	15.0	13.0	12.3	13.5	1.6
Final wt. (kg)	15.8^{c}	17.0^{d}	14.5^{b}	13.6^{a}	15.0^{b}	1.6
Average wt. gain (kg)	2.5^{c}	2.0^{b}	1.5^{a}	1.3^{a}	1.5^{a}	0.3
Growth rate (g/d)	41.7^{c}	33.3^{ab}	25^{b}	21.7^{a}	25^{b}	5.7
FCR	15.7	23.3	26.2	29.5	33.6	6.7

$^{a, b, c, d,}$ *Means with different superscripts in the same row are significantly different (P < 0.05).*
SEM = Standard Error of Means

6.4 Discussion

6.4.1 Proximate composition of the experimental feeds

The composition of the experimental diets (C0Z100, C25Z75, C50Z50, C75Z25 and C100Z0) is variable among the treatment diets, respectively. The composition of the basal diet, Rhodes grass hay, in this study in terms of DM, OM and CP was slightly lower than those reported in other studies (Ondiek *et al.,* 2010 and Kemboi, 2017). However, this study indicate high fibre content in terms of NDF and ADF of 683.55 and 513.65g/kg DM, respectively. These values were higher than those reported by Ondiek *et al. (*2010). The proportion C0Z100 indicate high CP, TEPHs and TETs than the other four diets. The ratio C100Z0 showed high DM, ADF and condensed tannins (911.04, 193.73 and 15.48 g/kg DM), respectively. The CP content of all the dietary treatments was above the minimum protein requirement (80g/kg DM) for optimal rumen microbial activity (Annison and Bryden, 1998). The CP content in this study exceeded the CP level of 11 to 13% required for supplying protein for animal maintenance and growth (NRC, 1981). In the current study, the CP content of the experimental diets was slightly lower than that reported by Waldroup and Smith (2008) that multipurpose trees contain 20% CP and above in their leaves. Nutrient composition of Ziziphus in the present study was lower than the values reported by Ondiek *et al.* (2010). These variations in the composition of experimental diets could be attributed to differences in proportion of mixtures, the species, sample preparation methods and the environment (Ondiek *et al.,* 2010).

6.4.2 Feed intake, apparent nutrient digestibility and nitrogen balance

Feed intake in the current study indicated high nutrient intake. The browse forages supplementation to basal diet (Rhodes grass) increased total dry matter intake whether singly or in combination. In this study, *Z. spina-christi* showed higher intake than *C. adenogonium*. This could be due to palatability and acceptability of Ziziphus over Combretum. Total dry matter intake increased with increasing inclusion levels of *Ziziphus spina-christi.* These results are in agreement with those of Muinga *et al.* (1995) and Ajayi *et al.* (2005) who reported that intake increased with the inclusion levels of mango leaves supplement. Similar findings have been reported by other authors working on different browse forages (Yusuf, 2011; Ondiek *et al.,* 2013 and Olusegun *et al.,* 2016). The preference of browse leaves by different species of animals have been reported in previous studies (Lowry, 1990; Shelton, 2000 and Fadiyimu *et al.,* 2011). High intake of *Ziziphus spina-christi* could also be due to low levels of anti-nutritional factors.

Apparent digestibility of the DM, OM, CP, NDF, ADF, was higher with high inclusion rate of *Ziziphus spina-christi* compared to *Combretum adenogonium*. Supplementing low quality roughage with browse leaves improved digestibility of the basal roughage. This may be attributed to the rumen degradable nitrogen in browse that may have increased microbial activity in the rumen that better utilized the basal diet. These findings are in agreement with those of Ademosun (1998) and Murro *et al*. (2003). High apparent nutrient digestibility was obtained in the highest inclusion level of *Ziziphus spina-christi* supplement, except for total extractable tannins. Olusegun *et al.* (2016) reported that high digestibility is an indication that the experimental diets had been well degraded in the rumen. Similar observations were reported by Hansen *et al.* (2007); Okoruwa *et al.* (2013); and Okoruwa and Bamigboye, (2015). According to observation by Ondiek *et al.* (2013) improvement in digestibility could also have resulted from reduced levels of acid detergent fibre (ADF) and lignin in the experimental diets. Nitrogen intake of the supplement was similar in the diets. However, goats feeding on a single supplement (C0Z100 and C100Z0) retained similar amount of nitrogen (1.62 and 1.65 g), respectively. The combination of browse at C25Z75 indicated significant retention of nitrogen than other experimental diets. Faecal nitrogen loss was high in C50Z50 and C75Z25 diets. Low nitrogen retention again was observed in similar diet combination, showing that *Combretum adenogonium* was poorly utilized by the goats. Reed and Soller (1987) reported high levels of faecal nitrogen in sheep fed *Acacia seyal*. They indicated that this fraction also referred to as metabolic increment which is an endogenous nitrogen resulting from higher production of rumen microbes is due to greater urea recycling from blood to rumen. Van Soest (1982) reported that faecal nitrogen composed of undegraded feed nitrogen, microbial nitrogen and endogenous nitrogen from digestive tract. According to Abdu *et al.* (2012) nitrogen balance showed significant difference of faecal nitrogen output on *Acacia auriculate.* The increased total nitrogen output observed in animals fed *Acacia auriculate* was the consequence of decreased nitrogen absorption caused by high contents of tannin in diet (Fassler and Lascano, 1995; and Woodward and Reed, 1997). Condensed tannins bind protein, making it less degradable in the rumen that it increases by-pass (undegradable protein) protein to the small intestine. Similar findings are reported by Bamikole and Babayemi (2004) that higher nitrogen retention of the diets could have resulted from high crude protein content of the forage.

6.4.3 Growth performance of cross-bred goats

The average live weight gain of goats offered sole *Ziziphus spina-christi* was the highest (2.62 kg) and the growth rate (43.75g/d) in the same treatment C0Z100 when compared to other treatments C25Z75, C50Z50, C75Z25 and C100Z0, respectively. The least value of gain (20.83 g/day) was obtained from sole diet of *Combretum adenogonium* supplement C100Z0. This may be attributed to poor acceptability and palatability of *Combretum adenogonium* diet. Significant improvement in average daily gain, mature body weight and feed conversion efficiency of small ruminants was reported when *Moringa oleifera* leaves substituted cottonseed cake (Murro *et al.,* 2003). Several findings reported on feed supplementation with different browse leaves reveal high live weight gain against basal or control diet (Sibibe and Williams, 2002; Aganga and Tshwenyane, 2003; Ndemanisho *et al.,* 2007 and Ondiek *et al.,* 2013). In the present study, growth rate decreased with increasing inclusion levels of *C. adenogonium*, while feed conversion efficiency increased with increasing levels of *C. adenogonium* although it manifested none significant difference.

6.5 Conclusion

Supplementing Rhodes grass basal diet increased total daily dry matter intake, nutrient digestibility and daily live weight gain. However, *Ziziphus spina-christi* was superior to *Combretum adenogonium* in most determined characteristics whether fed as sole or combined and therefore, it could serve as potential protein supplement to low-protein basal diets.

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CHAPTER SEVEN

Intake, nutrient utilization and growth performance of cross-bred goats fed graded levels of *Ziziphus spina-christi* foliage supplemented to Rhodes grass (*Chloris gayana*) hay

Abstract

Effect of supplementation of *Ziziphus spina-christi* leaves on diet intake, digestibility, nitrogen balance and growth performance of cross-bred goats fed a basal diet of Rhodes grass hay was studied. Sixteen cross-bred goats of both sexes with an average weight ranging from 15.5 ± 4 kg were randomly allocated to four dietary treatments (four animals per treatment) in a completely randomized block design. Intake and growth performance lasted eight weeks followed by one week digestibility and nitrogen balance trial. Four treatment diets T1, T2, T3 and T4 containing 0, 20, 30 and 40% DM *Ziziphus spina-christi*, respectively were used s supplementary feed. Results on DMI indicated significant ($P < 0.05$) difference among treatment diets with T3 and T4 being significantly ($P < 0.05$) higher than T2 and T1 (control). Diet digestibility and nitrogen balance were significantly ($P < 0.05$) different in all the treatments. Weight gain was negative in the control diet. The supplemented treatments did not differ ($P > 0.05$) significantly on weight gain, however, T3 at supplement level of 30% was superior to the other treatments (T1, T2 and T4). Feed conversion ratio was significantly ($P < 0.05$) different in all the diets. The results show that *Ziziphus spina-christi* can be supplemented up to 30% level to basal diet of hay without adverse effects and indicate good feed intake, digestibility and growth rate of goats.

Key words: goats, intake, supplement, weight gain, *Ziziphus spina-christi*

7.1 Introduction

In South Sudan, livestock is one of the major sources of livelihood to the majority of the population. However, livestock production has been hindered by several man-made and natural factors. Man-made problems include livestock theft/rustling and civil wars, while natural factors are dry season and drought period that lead to severe feed shortage. Most of the natural grasses and herbaceous plants become scarce during dry season, thus, diminished livestock production during that time of the year. In the tropics, some alternatives have been practiced to cope with feed scarcity such as the use of browse tree foliages. Browse fodders are capable of providing high-protein year round (Olivares-Perez *et al.,* 2011). The use of browse trees and shrubs as supplementary feed for livestock during dry season is well documented (Ondiek *et al.,* 2000; Osuga *et al.,* 2008; Kasale, 2013; Mangara *et al.,* 2017, Kemboi, 2017). Despite presence of anti-nutritive factors such as tannins that may reduce acceptability and palatability of browse forage, use of tree foliage results to better performance in goats (Ondiek *et al.,* 1999; Oloche *et al.,* 2015 and Mangara *et al.,* 2017), sheep (Ngwa *et al.,* 2003) and cattle (Abdulrazak *et al.,* 1996, Kasale, 2013). Therefore, this study evaluated feed intake, digestibility and live weight changes in goats fed graded levels of *Ziziphus spina-christi* foliage as supplement to Rhodes grass hay basal diet.

7.2 Materials and methods

7.2.1 Location of the study

The study was carried out at Tatton Agriculture Park, Dairy Goat Breeding and Multiplication Center, Egerton University, Kenya from 1st June to 8th August 2017. Average temperature and rainfall ranged from 17°C to 22°C and 900 to 1200 mm, respectively, (EUEMS, 2009).

7.2.2 Feed preparation

Leaves of *Ziziphus spina-christi* were collected from Central Equatoria State of the Republic of South Sudan. The leaf browses were harvested by hand plucking/clipping. The forage was dried in shade for seven days to avoid loss and bleaching, then ground to pass through a 4 mm screen, packed in gunny bags and transported to the experimental site at Egerton University. The basal diet of Rhodes grass hay was also milled to pass through a 4 mm screen.

7.2.3 Experimental animals, management and feeding

Sixteen cross-bred goats of both sexes were used. The animals were quarantined for one week before the actual experiment commenced. The animals were fed a basal diet of Rhodes grass hay and supplemented with the graded levels of *Ziziphus spina-christi*. The supplementation was offered at increasing levels as follows: L0, L20, L30 and L40% being the percentage of the total dietary intake denoted by T1, T2, T3 and T4, respectively. All sixteen goats were allocated to individual pens with raised slats in an open-sided house. Goats were put in pens each measuring 1 x 1.5 M; and fitted with feed trough and watering facility. The goats were routinely sprayed every two weeks using Dominex® 100 EC of which 10 ml was diluted with 20 L of water then sprayed using hand pump to control external parasites. All goats had free access to clean drinking water and mineral supplements (Vitaphos Biomin®) *ad libitum*. The supplement was fed twice daily at 0800 and 1600 hr and the basal diet was offered for the rest of the day.

7.2.4 Experimental design

The basal diet and the supplement were provided in a completely randomized design (CRD), 4 treatments with 4 animals were allocated randomly to the dietary treatments. Animals were blocked on initial weight. Animals were allowed free access to mineral salts and fresh water *ad libitum*. The supplement was preferentially fed at 0800 and 1600 hr and the basal diet made available *ad libitum* to determine intake. The performance trial lasted eight (8) weeks.

7.2.5 Digestibility and nitrogen balance trial

After eight (8) weeks of feeding experiment, the goats were used for the determination of digestibility and nitrogen retention. All the 16 animals were subjected to total collection of feces and urine. Four animals were allocated per treatment. Similar managerial practices were applied to goats and the facility as in the feeding trial. The experimental diet was offered at 0800 and 1600 hr and thereafter, followed by basal diet. Nitrogen loss from the urine was prevented by adding 10 ml of H_2SO_4 (10%) solution into the urine collection container.

7.2.6 Data collection

During the feeding trial, daily feed intake was calculated as feed offered less feed refusal. Weekly body weight of the animals was determined by weighing the animals. Parameters determined were: feed intake, average weight gain (final live weight minus initial live weight); average daily gain (average weight gain divided by sixty days experimental period); feed conversion ratio (daily dry matter intake divided by daily weight gain) and nitrogen balance. Feed refusals, faeces and urine were individually collected and weighed daily before morning feeding. Then 10% pool sample per animal was frozen and kept for later analyses.

7.2.7 Chemical analyses

Samples of all the collected feed offered, refusals and faeces were oven dried at 105°C and ground to pass through 1mm for chemical determination. The CP of Feed, faecal nitrogen and urine NH_3-N was measured by the Kjeldahl method (AOAC, 1990), and the ash content according to Van

Soest *et al.* (1991). Apparent nutrient digestibility was determined by difference of the nutrient content in feed and faeces. Nitrogen balance was calculated using the formula: Nitrogen Balance = Nitrogen Intake - (Faecal nitrogen + Urinary Nitrogen).

7.2.8 Statistical analysis

The data obtained on feed intake, final live weight and daily weight gain was subjected to analysis of variance (ANOVA) in a completely randomized design using the General Linear Model Procedures (proc glm) of the Statistical Package of SAS (2002). Significant means were separated using Tukey HSD (Tukey Honestly Significant Difference Test) at 5% significance level. The model under completely randomized design was used:

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

Where, Y_{ij} = dependent variables (DMI, AWG, DWG, FCR, ND and NR).

μ= overall mean due to all observations,

T_i = effect of i^{th} treatment diet $\{i = 1,2,3,4, \}$ and E_{ij} = Random error effect

7.3 Results

Table 21. Chemical composition of *Ziziphus spina-christi* and Rhodes grass (g/kg DM)

Forage species	DM	OM	CP	CF	EE	Ash	NFE
Ziziphus spina-christi	970.3	876.4	189.0	121.8	32.1	123.6	503.6
Rhodes grass	912.7	901.5	46.9	446.3	25.7	125.6	647.5

7.3.1 Feed intake of cross-bred goats fed graded levels of *Ziziphus spina-christi* (g/kg)

Table 21 shows the chemical composition of the dietary ingredients. *Ziziphus spina-christi* indicated high crude protein value (189.02 g/kg DM). Results of feed intake, digestibility and nitrogen retention is shown in Table 8.2. There was higher (P < 0.05) basal feed intake in T1 over the other treatments. Treatment three (T3) in the supplemented groups had similar intake (P > 0.05) to high than T4. Total dry matter intake for T3 and T4 was significantly (P < 0.05) higher than T1 and T2, respectively. Digestibility of CP, CF, EE and NFE was significantly (P < 0.05) higher in T3. Dry matter digestibility of the Control diet was much lower compared to T2, T3 and T4. Nitrogen intake was not significantly (P > 0.05) different in the supplemented diets (T2, T3 and T4), however, it was lower in the control diet (Table 22). There was no significant (P > 0.05) difference in faecal nitrogen loss among the three dietary treatments. Nitrogen retained was not significantly (P > 0.05) different throughout the supplemented treatments. However, supplementation level of 30% had high performance and was the best among other treatment levels.

Table 22. Feed intake, digestibility and nitrogen retention by cross-bred goats

parameters	**Dietary treatments**				
	T1 (0%)	T2 (20%)	T3 (30%)	T4 (40%)	SEM
Dry matter feed intake (g/day)					
Basal diet (Rhodes grass)	441.3^{b}	353.6^{a}	342.8^{a}	338.2^{a}	18.6
Supplement (Ziziphus)	0	127.4^{a}	242.2^{b}	208.4^{b}	28.3
Total feed intake	441.3^{a}	481.1^{b}	585.1^{d}	546.6^{c}	32.2
Digestibility coefficient (%)					
Dry matter	36.3^{a}	78.6^{b}	81.2^{b}	80.8^{b}	13.3
Crude protein	84.1^{a}	86.3^{a}	91.0^{b}	84.5^{a}	1.8
Crude fibre	41.4^{b}	47.2^{bc}	63.6^{c}	37.5^{a}	4.9
Ether extract	50.4^{b}	54.7^{c}	59.8^{d}	46.8^{a}	1.7
Nitrogen free extract	39.1^{a}	59.4^{b}	64.2^{c}	58.4^{b}	2.1
Nitrogen balance (g/day)					
Nitrogen intake	0.8^{a}	3.0^{b}	3.1^{b}	2.9^{b}	0.0
Faecal nitrogen	0.1^{a}	0.3^{b}	0.3^{b}	0.2^{b}	0.0
Urinal nitrogen	0.3^{a}	0.1^{a}	0.2^{b}	0.2^{b}	0.0
Nitrogen retained	0.5^{a}	2.6^{b}	2.5^{b}	2.5^{b}	0.0

$^{a, b, c, d}$ *Means with different superscripts in the same row are significantly different (P < 0.05).*
SEM = Standard Error of Means

7.3.2 Body weight gain of cross-bred goats fed graded levels of *Ziziphus spina-christi* supplemented to Rhodes grass (*Chloris gayana*) hay

Live weight changes of the goats is shown in Table 23. Treatment T1 (control) indicated negative daily gain and feed conversion ratio (FCR). Daily weight changes was not significantly (P > 0.05) different in all the supplemented diets. Supplement level of 30% (T3) had high daily gain (32.14

g/day) than T2 and T4 (29.46 and 27.23 g/day), respectively. The FCR was significantly ($P < 0.05$) high in T3 and T4; and lower in T2, while control diet (Rhodes grass), T1 had negative feed conversion ratio. Level 30% (T3) had high daily weight gain and feed conversion ratio. This implied that the higher the value of FCR, the less desirable the feed, as the animal consumes more feed to produce a unit of weight gain. This means that the feed was better utilized at the lower level of inclusion that gave a FCR of 4.38 at 20% inclusion level.

Table 23. Live weight gain

parameters	Dietary treatments				
	T1 (0%)	T2 (20%)	T3 (30%)	T4 (40%)	SEM
Body weight gain					
Initial weight (kg)	19.7	12.8	14.5	15.9	1.9
Final weight (kg)	19.2^{c}	14.4^{a}	16.2^{b}	17.4^{b}	1.8
Daily weight gain (g/day)	$- 9.8^{a}$	29.5^{b}	32.1^{b}	27.2^{b}	3.4
FCR	- 67.8	19.1	16.6	20.6	11.1

$^{a, b, c,}$ Means with different superscripts in the same row are significantly different ($P < 0.05$).
T1, T2, T3 and T4 (Treatments), FCR= feed conversion ratio, SEM = Standard Error of Means

7.4 Discussion

The crude protein content of 189 g/kg of *Ziziphus spina-christi* in the diet was higher than the minimum requirement of goats 7.7% for maintenance (NRC, 1981). This CP content was adequate to provide the minimum rumen ammonia levels required for optimum activity of rumen micro-organisms (Norton, 2003). All the experimental goats had adequate dry matter intake (DMI) which ranged from 441.25 to 585.11 g/animal. These values were higher than those ranging from 288.48 to 354.49 g/animal/day for WAD goats fed *Moringa oleifera, Gliricidia sepium* and *Leucaea leucocephala* dried leaves as supplements to cassava peels (Asaolu *et al.,* 2012), but similar to those reported by Ajayi *et al.* (2005) for *Mangifera indica, Ficus thionningii, Gliricidia sepium* foliages and concentrates as supplements to basal diet of Guinea grass (*Panicum maximum*). Ondiek *et al.* (2013) also reported high DM intake of 442 and 449 g/day of the diet supplemented with *Balanites aegyptiaca* and *Acacia tortilis*, respectively. The values obtained in this study met the minimum daily dry matter intake (DMI) recommended for small ruminants (NRC, 1985).

The DM digestibility did not differ (P > 0.05) significantly across supplemented treatments, however, it increased with supplementation from 36.3 g/kgDM for the control to 81.2 g/kgDM for treatments supplemented with *Ziziphus spina-christi*. Crude protein digestibility also increased linearly in the supplemented diets and the highest was recorded at 30% level of inclusion. This suggest that the diet was well utilized by the goats. These results agree with those from other reports (Ondiek *et al.,* 2000; Shumuye and Yayneshet, 2011 and Tona *et al.,* 2014). The highest digestibility of dry matter (DM) was observed in the animals fed 30% of *Ziziphus spina-christi* foliage. The digestibility coefficients of CP, CF, EE and NFE followed to a high extent similar trend as the dry matter digestibility and is similar to those reported by Yusuf (2011) who found highest DM digestibility in animals fed 30% of mango leaf as well as the study of Arigbede *et al.* (2005) who found that the digestibility coefficients of OM, CP, NDF, ADF and ADL followed the same trend as the DM digestibility coefficients in diets containing graded levels of combinations of *Grewia pubescens* and *Panicum maximum*. The higher digestibility of DM and CP in goats supplemented with *Ziziphus spina-christi* leaves might be due to higher crude protein intake and lower tannin content. These results concur with the reports of Kumar and Vaithiyanathan (1990) and Shumuye and Yayneshet (2011).

There was no significant difference in nitrogen intake, loss and retained among all the supplemented goats, however, there was significant difference between control and the supplemented treatments. Supplementation with the graded levels of *Ziziphus spina-christi* improved nitrogen retention in the goats. Nitrogen retention of Ziziphus supplemented basal diets were significantly higher than that of control (Rhodes grass) alone and decreased with increasing levels of supplementation with T2 having higher nitrogen retention but it was not significantly different from T3 and T4. Goats receiving diets supplemented with *Ziziphus spina-christi* had better utilization of nitrogen thus improved performance. These findings agree with report of Veereswara *et al.* (1993) who observed that the digestibilty of nitrogen in Sesbania, Gliricidia and Leucaena species was 85.5, 77.3 and 80.0%, respectively. This indicating potential value of tree legume leaves as nitrogen supplements to low quality roughages. Thus, tree legumes growing in Sub-Saharan countries can play an important role in maximizing utilization of grass forages and improving animal production (Mpairwe *et al.,* 1998) by the provision of adequate nitrogen. The supplemented animals had significantly higher daily weight gain compared to the animals fed on

Rhodes grass (control) alone. Daily weight gain was highest for the 30% inclusion level of the supplement (T3) while the control had negative gain. In this study daily gain ranged from 27.23 to 32.14 g/day and these were lower than those reported by Mpairwe *et al.* (1998) who reported an average daily weight gain of 17.9, 80.4, 89.3 and 71.4 g day^{-1} for the 0, 4, 8, and 12g levels of Gliricidia supplementation. Solomon *et al.* (2004) reported a daily live weight gain range of 21.6 to 36.3g/day when Menz ewes were fed teff straw basal diet supplemented with different multi-purpose trees which agree with the findings of the present study. Browse forages supplemented with different basal diets provide adequate intake. This can be attributed to the nitrogen browse forages supply that increase microbial activity in the rumen increasing intake of the low quality feed.

Ondiek *et al.* (2013) reported low average daily gain (8.33g/d) for control animals which initially lost weight due to adjusting from free grazing to confinement and restricted feeding with no free choice to forage. Several authors reported weight loss when small ruminants were fed unsupplemented crop residues or natural grass hay as basal diet which had poor nutrient content (Getahun, 2006; Berhan and Getachew, 2009; and Takele and Getachew, 2011). Ndemanisho *et al.* (2007) reported values similar to those in the current study (22.1±3.18 to 25.4±3.09 g/d) for crossbred dairy goats fed maize stover and supplemented with tree browse. According to Mpairwe *et al.* (1998) significant difference they observed in weight gain between the control and supplemented treatments could have been attributed to increased crude protein intake; dry matter and crude protein digestibility. The feed conversion ratio found in this study was lower for diets of 30% and 40% supplemental level compared with 0% and 20% inclusion. This observation was similar to the findings reported by Murro *et al.* (2003) who reported lower feed conversion ratio in the higher inclusion rate of meal M (66) and M (100) compared with M (0) and M (33).

7.5 Conclusion

It can be concluded from this study that supplementing goats feeding low quality forage (Rhodes grass) basal diet with browse foliage increased performance. In the current study, goats fed 30% inclusion level of *Ziziphus spina-christi* had better performance results in terms of diet intake, feed digestibility and live weight gain than those on 20% and 40% inclusion rate.

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CHAPTER EIGHT

8.1 GENERAL DISCUSSION

The results of the present study indicated that majority of the respondents were aged above 41 years which enhances the reliability of the information obtained. Most of the youth between the ages of 21-40 prefer other income generating activities associated with migration to urban centers (Ansah and Nagbila, 2011**).** Livestock and livestock products as well as feed resources received little attention with regards to research and development in CES of South Sudan. This could be due to the fact that South Sudan mostly rely on oil production as the only source of income. Although livestock play an important role in the livelihood of most South Sudanese people and thus contributes to food security, policy makers have given little attention to the development of this sector.

In the present study, gender significantly ($P < 0.01$) influenced livestock ownership where males were the majority although females also played a significant role. This could be attributed to the role livestock play in South Sudanese communities. Similar results were reported by Preston (2008), Gaiballa and Lee (2012), and Noor *et al.* (2012). In the current study, majority of the respondents attended primary school and only 11.6% indicated they have never gone to school. This implies that majority of the livestock keeping communities were engaged in livestock activities that render them little opportunity to attend school. These findings agree with those reported by Noor *et al.* (2012). Majority of livestock owners indicated sheep and goats are of significant importance to their livelihood compared to other sources such as cattle, business, formal employment, crop farming and remittances. This could be due to ease of managing sheep and goats compared to cattle. Also because of their relatively small size compared to cattle. Sheep and goats are easily sold when need arises. The results of the survey also showed that almost every household interviewed owned sheep and goats. The relative importance of livestock as a source of livelihood observed in this study is in agreement with previous reports from Kenya (Guliye *et al.,* 2007 and Noor *et al.,* 2012). There is significant contribution of livestock resources to socio-cultural needs of the households, especially in payment of dowry, compensation for murder/injury, cultural ceremonies and performance of rituals. The importance of livestock for socio-cultural needs of pastoral communities in Northern Kenya were also described by Guliye *et al.* (2007). The results of the present study indicate that majority of the livestock keepers purchased their foundation herd.

Similar findings were also reported in Kenya on camels (Noor *et al.,* 2012). Livestock resources being the main source of livelihood amongst the communities, could have motivated the purchase of foundation herd. In this study, peri-urban livestock production system is practiced by large number of livestock owners than the pastoral system. The former is mainly practiced by the small scale farmers for subsistence, while the latter is mostly practiced by the pastoral communities who keep large number of livestock for livelihood and social prestige. Majority of the respondents indicated that keeping livestock around urban centers is necessary to sustain easy access to urban social amenities (schools, hospitals, infrastructure, business opportunities, etc.). Others indicated easy access to urban market for livestock and livestock products and improved security. The current study show that communally owned land provided significant areas for the grazing of livestock.

The results indicate browse trees are an important livestock feed resource which is in agreement with previous findings (Petit and Diallo, 2001; Shelton, 2004; Ansah and Nagbila, 2011; and Belete *et al.,* 2012). The results of this survey show only the most common browses in the three study locations. The results also indicate that almost all ruminant livestock utilized browse forage. These findings collaborate with those of Ansah and Nagbila (2011) and Gaiballa and Lee (2012) who reported that both leaves and pods are used by various kinds of livestock and wildlife. Some browses shown in this study were also reported by Gaiballa and Lee (2012) as important browses in Western Bahr El Ghazal State of South Sudan. This representation indicate that potential browses that could be used as livestock feed are common and abundant in the study area. In the current study, the parts of tree browses being utilized by the livestock indicate the trees are important forage resource. This results agree with Le Hourou (1980) who explained that, the idea of browse is complex depending on the plant species, animal species, forage availability and accessibility and the nutritional status of the animals.

The respondents surveyed reported that *Ziziphus spina-christi, Acacia nilotica, Combretum adenogonium, Sclerocarya birrea, Balanite aegyptiaca, Afzelia Africana and Tamarindus indica* are the most common browses for livestock in CES of South Sudan. These findings are similar to those of Smith (1986) on browse trees and shrubs use in tropical Africa, and Giffard (1971) who reported the important browse species in the humid tropical West African zone. In this study, the respondents indicated that browse species such as *Acacia, Combretum, Ziziphus, Sclerocarya* and *Balanites* are valuable because of the ability to produce green leaves in the dry season for livestock feeding. These five indigenous tree browses identified as most important were evaluated. Two were found to have more potential (*Combretum adenogonium* and *Ziziphus spina-christi)* due to their nutritive value and *in vitro* digestibility and therefore, were used for animal performance trials. The two browses observed to have high crude protein values that ranged from 120 to 201 g/kg DM. These values are higher than those reported for low quality feed (30-50 g/kg DM) by Leng (1997); for pasture grass (48 to 52 g/kg DM) by Devendra, (1993); and for Rhodes grass (52 g/kg DM and 47 g/kg DM) reported by Ondiek *et al.* (2010) and Mangara *et al.* (2017), respectively. The CP reported in this study is higher than the minimum requirement of 80 g/kg DM needed for optimal rumen microbial function (Annison and Bryden, 1998).

The fibre fraction in this study ranged from 148-319 g/kg DM (NDF) and 150-281 g/kg DM (ADF). These values were lower than those reported by Ondiek *et al.* (2010) for different browse forages. The lower the NDF and the higher ADF fractions in feeds, the higher the digestible organic matter and expected metabolizable energy value (Ondiek, 2012). In this study, all browse trees except *B. aegyptiaca* and *Z. spina-christi* had high phenolic and tannin contents greater than the 50 mg/g DM reported to be the minimum beneficial level in ruminants (Mangan, 1988) since high levels of condensed tannins may interfere with the availability of organic matter in the feed (Reed, 1986 and Ondiek, 2012). However, according to Makkar (2003), reduction in digestion of feeds by tannins could increase synchronization and release of various nutrients which might be responsible for increase in microbial efficiency. High synthesis of microbial protein can be obtained with higher proportion of degraded substrate causing increase of microbial load in the rumen. This action together with decrease in protein degradability are beneficial for ruminants as they increase supply of non-ammonia nitrogen in the lower intestine resulting in high productivity of milk, meat and wool (Makkar, 2003 and Ondiek, 2012). These browses were found to contain adequate amount of macro and micro mineral content and can be used as supplement to ameliorate mineral deficiency in livestock. High mineral contents in browse foliages were also reported by Le Houerou (1980); Abdulrazak *et al.* (2000) and Ondiek (2010). Higher levels of phenolics and tannins observed in the present study, however, did not greatly interfere with the degradability of the forages. Results of this study indicate that *B. aegyptiaca*, *C. adenogonium* and *Z. spina-christi* are highly degradable and fermentable. However, the most highly degradable browses are *C. adenogonium* and *Z. spina-christi* because they have higher OM degradability. Supplementing goats fed on poor quality feed with these browse leaves showed better performance in terms of intake, digestibility and live weight changes. In this study, increase in feed intake, digestibility and growth performance could be attributed to supplementation with *Z. spina-christi* and *C. adenogonium* which have high crude protein content. The positive responses in feed intake due to tree leaves supplementation was also reported by Premaratne *et al.* (1998) who supplement straw basal diets with either urea or legume forages, Ondiek *et al.* (2010) and Kemboi (2017) who supplemented Rhodes grass hay with browse tree leaf forages.

The increased intakes and digestibilities resulted in increase in live weight gain of goats (20.83 and 43.75 g/d) and the highest gain was observed when *Z. spina-christi* was used as sole supplement. According to Nherera *et al.* (1998) and Ondiek (2012), lower growth rates than expected from the retained nitrogen could be attributed to the fact that, nitrogen loss in faeces may be underestimated due to binding effect of tannins which may have resulted in an overestimation of the retained nitrogen. In this study, supplementation with tree forages improved intake, digestibility and weight gain than the control which had a negative weight gain.

8.2 General conclusions

The following conclusions can be drawn from these studies

1. Majority of the livestock owners interviewed are elderly and therefore knowledgeable about various browse resources available. There are diverse types of trees and shrubs that are important browses for animals in CES of South Sudan. Livestock keepers have indigenous knowledge on utilization of different tree browses by ruminant animals.
2. Indigenous tree species have high crude protein and low fibre contents. However, the browses contained high levels of phenolic and tannins, higher than 50 g/kg DM, the maximum tolerable limit by ruminants. These higher levels could decrease the nutritive potential of these browses. The Browse species had mineral levels higher than the dietary requirements and therefore, can provide adequate sources of mineral supplements to ruminant livestock.

3. Tree browse species have prosing potential as feed for ruminant livestock as shown by high organic matter degradability. High degradability increase nitrogen available in the rumen thus, increasing microbial load in the rumen that can digest more of poor quality roughages.
4. Supplementing Rhodes grass basal diet increased total daily dry matter intake, nutrient digestibility and daily live weight gain. *Ziziphus spina-christi* browse forage was superior to *Combretum adenogonium* whether fed as sole or combined. Therefore, it can serve as potential protein supplement to poor quality diets.
5. Supplementing goats feeding on low quality forage with browse forage increased performance. *Ziziphus spina-christi* should be supplemented at 30% inclusion rate for better diet intake, feed digestibility and live weight gain.

8.3 Implications of the study

1. Browse forages from indigenous trees can be used as protein supplements for livestock feeding on poor quality forages as basal diet, especially during dry season.
2. The browse forages can be good sources of mineral supplements to alleviate mineral deficiency in livestock
3. The leaf forages can be harvested, processed and stored to be used as supplements to low quality feeds.

8.4 Further work

1. Further research should be done on the nutritive value of all reported browse trees and shrubs.
2. This study also recommends more screening of the predominant and preferred browse species for nutritional evaluation under practical feeding systems.
3. Livestock keepers should be offered extension services on better methods of preservation/conservation and supplementation of these browse forages for the better utilization to boost livestock production in the dry season.

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APPENDIX

Scientific peer reviewed publications from this thesis

a) Published papers

1. **Mangara, J.L.I., Guliye, A.Y., Migwi, P.K. and Ondiek, J.O. (2017).** Predominant and most preferred indigenous tree browses as feed for ruminant livestock in Central Equatoria State of the Republic of South Sudan. *Researchjournali's Journal of Agriculture, 4(2).* www.researchjournali.com
2. **J L I Mangara, A Y Guliye, P K Migwi and J O Ondiek. (2017).** Nutrient composition of selected indigenous tree browses in Central Equatoria State of the Republic of South Sudan. *Livestock Research for Rural Development, 29(4).* http://www.lrrd.org.
3. **Mangara, J. L. I., Guliye, A.Y., Migwi, P. K. and Ondiek, J.O. (2017).** Evaluation of *in vitro* dry matter digestibility of selected indigenous tree browses as feed for ruminant livestock in Central Equatoria state of the Republic of South Sudan. *International Journal of Development Research, 7:12533-12539.* http://www.journalijdr.com.

b) Submitted papers

1. **J L I Mangara, A Y Guliye, P K Migwi, and J O Ondiek. (2018).** Nutrient utilization and growth performance of cross-bred goats fed *Ziziphus spina-christi* and *Combretum adenogonium* forages, singly and in various combinations supplemented to Rhodes grass (*Chloris gayana*) hay. http://www.lrrd.org.
2. **J L I Mangara, A Y Guliye, P K Migwi and J O Ondiek (2018).** Intake, nutrient utilization and growth performance of cross-bred goats fed graded levels of *Ziziphus spina-christi* supplemented to Rhodes grass (basal diet) hay. http://www.lrrd.org.

SURVEY QUESTIONNAIRE FOR LIVESTOCK PRODUCERS

Questionnaire to identify the most preferred indigenous tree browses as feed for livestock in Central Equatoria State of South Sudan.

Questionnaire number ____________________________________

Enumerator's name ______________________________________

Date of interview DD _______ MM _______YEAR__________ Location_______________

County ___________________________

A. Herd owner/respondent characteristics

Record personal details about herd owner or hired caretaker.

Particulars/characteristics	**Herd owner details**
1.1 Name	
1.2 Gender: 1 Male 2 Female	
1.3 Age (in years)	
1.4 Ethnic affiliation	
1.5 Educational level	
1.6 Major occupation	

Ethnic affiliation

1. Bari
2. Kuku
3. Pojulu
4. Nyangwara
5. Kakwa
6. Mundari
7. Lokoya
8. Lulubo
9. Others (specify)

Education level

0. None
1. Primary
2. Secondary
3. Post-secondary college
4. University

Major occupation

0. None
1. Livestock keeping
2. Business
3. Formal employment
4. Others (specify)

B. Livestock ownership and production objectives

1. Rank importance of livestock compared to other sources of livelihoods to your household needs:

Cattle	**Sheep and goats**	**Business**	**Formal employment**	**Crop farming**	**Remittances**

3 = Highest importance; 2 =Average importance; 1 = Low importance; 0 = No importance

2. Was your first/foundation herd acquired through? ☐ Tick the correct answer.

- Inheritance from family ☐
- Purchase ☐
- Both inheritance and purchase ☐

3. Rank the contribution of livestock to your household needs:

	Rank
1. Milk for selling	
2. Progenies (offspring) sale	
3. Transportation means	
4. Socio-cultural needs (e.g. dowry)	
5. Cash from recreation (e.g. riding, racing)	
6. Form of wealth	

3 = Highest importance; 2 = Average importance; 1 = Low importance; 0 = No importance

4. Record the total number of livestock in the herd:

	Livestock number
Owned by the household	
Kept but not owned by the household	
Total number of livestock in the herd	

5. How did the recent dry season affect your livestock?

Species	**Lost (Died)**	**Survived**
1. Cattle		
2. Sheep		
3. Goats		

C. livestock management systems

1. State the system of livestock keeping you practice:

Presently	≤ 10 years ago	> 10 years ago

1 = Only pastoral system; 2 = Peri-urban/semi-sedentary system

2. Rank the reasons that necessitated you to adopting the present system of livestock keeping

	Rank
1. System is traditional in this area	
2. Extension officers and other promoters influence	
3. Found the system more suiting to urban conditions	
4. Any other reasons (specify)	

3 = Highest importance; 2 = Average importance; 1 = Low importance; 0 = Not of any importance

3. Rank factors that encourage keeping of livestock around Juba town.

Factors	**Rank**
1. Pastures and water available	
2. Easy access to urban market for livestock and livestock products	
3. Easy access to better urban social amenities including schools, hospitals, roads, business opportunities	
4. Improved security	
5. Other reasons (specify)	

3 = Highest importance; 2 = Average importance; 1 = Low importance; 0 = Not of any importance.

4. Rank the importance of the following types of land ownership for the grazing of your livestock herd:

Types of land ownership	**Rank**
1. Communally owned land	
2. Government owned land	
3. Self-owned land	
4. Land leased from others	

3 = Highest importance; 2 = Average importance; 1 = Low importance; 0 = Not of any importance.

D. Feed resources

1. Rank the importance of the following feeds for feeding your livestock herd:

Types of feed resource	**Rank**
1. Native browses (Trees and shrubs)	
2. Native grasses	
3. Non-traditional feed resources e.g. Euphorbia	
4. Cultivated forages	
5. Crop residues	
6. Purchased commercial feeds	
7. Others (Specify)	

3 = Highest importance; 2 = Average importance; 1 = Low importance; 0 = Not of any importance.

2. List the trees (forages) predominantly browsed by livestock during wet or dry seasons in this area:

Wet season	**Dry season**
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.

NB: Can use local names, but will be translated.

3. Please indicate some of the browse trees that you know

S/NO	Common name	Vernacular name	Botanical name (if Known)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

4. Of the tree browses listed in (3) above, indicate those that are used by your livestock

1. ____
2. ____
3. ____
4. ____
5. ____

5. Part of the browse tree used

1. Fruits 2. Leaves 3. Pods 4. Seeds 5. Bark

6. Benefits or problems of feeding tree browses

Have you noticed any beneficial or harmful effects of tree browses after animals have eaten them? Please indicate in the table below

S/No.	Tree species (local or Vernacular name)	Eaten by goats, Sheep and cattle	Effects noticed	Any other comment

E. Feeding strategies

1. How far (in Km) do you go grazing your herd from this area during the different seasons?

Wet season	**Dry/drought season**

2. How severe is the feed shortage in your location during the different seasons?

Wet season	**Dry season**	**Drought periods**

3 = Shortage very severe; 2= Shortage moderately severe; 1 =Shortage low; 0 = No shortage

3. Rank how frequently you apply the following feeding strategies during times of moderate to severe shortage

Feeding strategies	**Rank**
1. Send livestock to "*forra*' (satellite) camps	
2. Rent/lease grazing pastures	
3. Split the herd by classes for preferential feeding	
4. Purchase of more commercial feeds	
5. Use my own cultivated forages	
6. Use more of non-traditional feeds	
7. Prolong daily grazing time	

3 = Most frequent practice; 2 = Frequent but not the most practice; 1 = Less frequent practice

0 = Not practiced at all.

F. Herd Structure and breed preference

1. Record the total number of all livestock in the herd of the different classes:

Classes	**Males**	**Females**
1. before weaning		
2. Immature		
3. Adult (Breeding)		
4. Castrates		
TOTAL		

Key data analysis output

Dependent Variable: OM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	323.0960000	80.7740000	23.51	<.0001
Error	10	34.3533333	3.4353333		
Corrected Total	14	357.4493333			

R-Square	Coeff Var	Root MSE	OM Mean
0.903893	2.784096	1.853465	66.57333

Dependent Variable: DM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	11.61196000	2.90299000	39.15	<.0001
Error	10	0.74153333	0.07415333		
Corrected Total	14	12.35349333			

R-Square	Coeff Var	Root MSE	DM Mean
0.939974	0.294775	0.272311	92.37933

Dependent Variable: CP

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	138.4549067	34.6137267	11.81	0.0008
Error	10	29.2984667	2.9298467		
Corrected Total	14	167.7533733			

R-Square	Coeff Var	Root MSE	CP Mean
0.825348	10.07186	1.711679	16.99467

Dependent Variable: CF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	260.9173600	65.2293400	45.55	<.0001
Error	10	14.3189333	1.4318933		
Corrected Total	14	275.2362933			

R-Square	Coeff Var	Root MSE	CF Mean
0.947976	7.812179	1.196617	15.31733

Dependent Variable: EE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	7.49030667	1.87257667	10.76	0.0012
Error	10	1.74066667	0.17406667		
Corrected Total	14	9.23097333			

R-Square	Coeff Var	Root MSE	EE Mean
0.811432	11.98429	0.417213	3.481333

Dependent Variable: Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	83.31110667	20.82777667	194.49	<.0001
Error	10	1.07086667	0.10708667		
Corrected Total	14	84.38197333			

R-Square	Coeff Var	Root MSE	Ash Mean
0.987309	3.975553	0.327241	8.231333

Dependent Variable: NDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	823.0217067	205.7554267	1378.26	<.0001
Error	10	1.4928667	0.1492867		
Corrected Total	14	824.5145733			

R-Square	Coeff Var	Root MSE	NDF Mean
0.998189	1.957459	0.386376	19.73867

Dependent Variable: ADF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	336.3021733	84.0755433	9.14	0.0023
Error	10	92.0308667	9.2030867		
Corrected Total	14	428.3330400			

R-Square	Coeff Var	Root MSE	ADF Mean
0.785142	14.62145	3.033659	20.74800

Dependent Variable: ADL

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	195.9051333	48.9762833	170.73	<.0001
Error	10	2.8686000	0.2868600		
Corrected Total	14	198.7737333			

R-Square	Coeff Var	Root MSE	ADL Mean
0.985569	5.433816	0.535593	9.856667

Dependent Variable: tct

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	5.55401599	1.38850400	164.25	<.0001
Error	10	0.08453390	0.00845339		
Corrected Total	14	5.63854989			

R-Square	Coeff Var	Root MSE	tct Mean
0.985008	6.826133	0.091942	1.346917

Dependent Variable: Ca

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	410.2838267	102.5709567	619.36	<.0001
Error	10	1.6560667	0.1656067		
Corrected Total	14	411.9398933			

R-Square	Coeff Var	Root MSE	Ca Mean
0.995980	2.610761	0.406948	15.58733

Dependent Variable: P

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	10.25643707	2.56410927	36.71	<.0001
Error	10	0.69845067	0.06984507		
Corrected Total	14	10.95488773			

R-Square	Coeff Var	Root MSE	P Mean
0.936243	11.36763	0.264282	2.324867

Dependent Variable: Na

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	199.5682929	49.8920732	738.67	<.0001
Error	10	0.6754287	0.0675429		
Corrected Total	14	200.2437216			

R-Square	Coeff Var	Root MSE	Na Mean
0.996627	0.270915	0.259890	95.93040

Dependent Variable: K

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	400.6828164	100.1707041	6972.50	<.0001
Error	10	0.1436653	0.0143665		
Corrected Total	14	400.8264817			

R-Square	Coeff Var	Root MSE	K Mean
0.999642	0.978096	0.119860	12.25447

Dependent Variable: Mg

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	59.77553867	14.94388467	156.96	<.0001
Error	10	0.95207667	0.09520767		
Corrected Total	14	60.72761533			

R-Square	Coeff Var	Root MSE	Mg Mean
0.984322	6.313410	0.308557	4.887333

Dependent Variable: Cu

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	7049.402667	1762.350667	11697.0	<.0001
Error	10	1.506667	0.150667		
Corrected Total	14	7050.909333			

R-Square	Coeff Var	Root MSE	Cu Mean
0.999786	0.404640	0.388158	95.92667

Dependent Variable: Zn

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	7137.857333	1784.464333	1433.69	<.0001
Error	10	12.446667	1.244667		
Corrected Total	14	7150.304000			

R-Square	Coeff Var	Root MSE	Zn Mean
0.998259	1.165531	1.115646	95.72000

Dependent Variable: Fe

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	138308.2893	34577.0723	93451.5	<.0001
Error	10	3.7000	0.3700		
Corrected Total	14	138311.9893			

R-Square	Coeff Var	Root MSE	Fe Mean
0.999973	0.414150	0.608276	146.8733

Dependent Variable: Co

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	2202750.740	550687.685	564.86	<.0001
Error	10	9749.080	974.908		
Corrected Total	14	2212499.820			

R-Square	Coeff Var	Root MSE	Co Mean
0.995594	1.155784	31.22352	2701.500

Dependent Variable: Mn

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	233.8466667	58.4616667	1201.27	<.0001
Error	10	0.4866667	0.0486667		
Corrected Total	14	234.3333333			

R-Square	Coeff Var	Root MSE	Mn Mean
0.997923	4.441716	0.220605	4.966667

Dependent Variable: A

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	2.02543107	0.50635777	12.88	0.0006
Error	10	0.39301467	0.03930147		
Corrected Total	14	2.41844573			

R-Square	Coeff Var	Root MSE	A Mean
0.837493	40.00659	0.198246	0.495533

Dependent Variable: B

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	32.57997160	8.14499290	33.77	<.0001
Error	10	2.41219533	0.24121953		
Corrected Total	14	34.99216693			

R-Square	Coeff Var	Root MSE	B Mean
0.931065	18.82680	0.491141	2.608733

Dependent Variable: C

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	211.6434727	52.9108682	192.57	<.0001
Error	10	2.7475647	0.2747565		
Corrected Total	14	214.3910373			

R-Square	Coeff Var	Root MSE	C Mean
0.987184	25.76207	0.524172	2.034667

Dependent Variable: RSD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	8.77391160	2.19347790	10.09	0.0015
Error	10	2.17323933	0.21732393		
Corrected Total	14	10.94715093			

R-Square	Coeff Var	Root MSE	RSD Mean
0.801479	31.04281	0.466180	1.501733

Dependent Variable: AB

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	28.25815952	7.06453988	49.49	<.0001
Error	9	1.28465933	0.14273993		
Corrected Total	13	29.54281886			

R-Square	Coeff Var	Root MSE	AB Mean
0.956515	13.29245	0.377809	2.842286

Dependent Variable: IW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	16.3000000	4.0750000	0.37	0.8252
Error	15	164.5000000	10.9666667		
Corrected Total	19	180.8000000			

R-Square	Coeff Var	Root MSE	IW Mean
0.090155	24.71340	3.311596	13.40000

diets	IW LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	13.2500000	1.6557979	<.0001	1
2	15.0000000	1.6557979	<.0001	2
3	13.0000000	1.6557979	<.0001	3
4	12.2500000	1.6557979	<.0001	4
5	13.5000000	1.6557979	<.0001	5

Dependent Variable: FW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	25.7950000	6.4487500	0.61	0.6596
Error	15	157.7225000	10.5148333		
Corrected Total	19	183.5175000			

R-Square	Coeff Var	Root MSE	FW Mean
0.140559	21.29825	3.242658	15.22500

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

diets	FW LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	15.8750000	1.6213292	<.0001	1
2	17.0000000	1.6213292	<.0001	2
3	14.5750000	1.6213292	<.0001	3
4	13.6750000	1.6213292	<.0001	4
5	15.0000000	1.6213292	<.0001	5

Dependent Variable: AWG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	4.84500000	1.21125000	2.57	0.0809
Error	15	7.07250000	0.47150000		
Corrected Total	19	11.91750000			

R-Square	Coeff Var	Root MSE	AWG Mean
0.406545	38.68499	0.686659	1.775000

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

diets	AWG LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	2.62500000	0.34332929	<.0001	1
2	2.00000000	0.34332929	<.0001	2
3	1.57500000	0.34332929	0.0004	3
4	1.42500000	0.34332929	0.0009	4
5	1.25000000	0.34332929	0.0024	5

Dependent Variable: GR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1345.825030	336.456258	2.57	0.0808
Error	15	1964.358450	130.957230		
Corrected Total	19	3310.183480			

R-Square	Coeff Var	Root MSE	GR Mean
0.406571	38.68190	11.44365	29.58400

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

diets	GR LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	43.7500000	5.7218273	<.0001	1
2	33.3350000	5.7218273	<.0001	2
3	26.2500000	5.7218273	0.0004	3
4	23.7525000	5.7218273	0.0009	4
5	20.8325000	5.7218273	0.0024	5

Dependent Variable: IW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	105.6500000	35.2166667	2.36	0.1226
Error	12	178.9000000	14.9083333		
Corrected Total	15	284.5500000			

R-Square	Coeff Var	Root MSE	IW Mean
0.371288	24.55409	3.861131	15.72500

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

diets	IW LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	19.7500000	1.9305655	<.0001	1
2	12.8000000	1.9305655	<.0001	2
3	14.4500000	1.9305655	<.0001	3
4	15.9000000	1.9305655	<.0001	4

Dependent Variable: FW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	47.8868750	15.9622917	1.12	0.3783
Error	12	170.4875000	14.2072917		
Corrected Total	15	218.3743750			

R-Square	Coeff Var	Root MSE	FW Mean
0.219288	22.39439	3.769256	16.83125

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

diets	FW LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	19.2000000	1.8846281	<.0001	1
2	14.4500000	1.8846281	<.0001	2
3	16.2500000	1.8846281	<.0001	3
4	17.4250000	1.8846281	<.0001	4

Dependent Variable: DWG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	4713.366457	1571.122152	34.63	<.0001
Error	12	544.477297	45.373108		
Corrected Total	15	5257.843754			

R-Square	Coeff Var	Root MSE	DWG Mean
0.896445	34.09899	6.735956	19.75413

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey

diets	DWG LSMEAN	Standard Error	Pr > |t|	LSMEAN Number
1	-9.8210000	3.3679782	0.0129	1
2	29.4637500	3.3679782	<.0001	2
3	32.1422500	3.3679782	<.0001	3
4	27.2315000	3.3679782	<.0001	4

Republic of South Sudan

Ministry of Agriculture and Food Security

Director General's Office

Ref: MAFs/RSS/I/2.E.2 Date: 6/12/2016

PHYTOSANITARY CERTIFICATE

1 To: the Plant Protection Organization(s) of:	2 Phytosanitary Certificate No.
Kenya	**00918**
I. DESCRIPTION OF CONSIGNMENT	
3 Name and Address of Exporter:	4 Declared Name and Address of Consignee:
Department of Animal Sciences, Faculty of Agriculture, Egerton University/Kenya	**John Loro Iga Mangara/Kenya**
5 Place of Origin:	6 Declared Means of Conveyance:
SOUTH SUDAN	**By Land**
7 Declared Point of Entry:	8 Distinguishing Marks:
Nimule- Through Busia to Kenya	**NONE**
9 Number and Description of Packages:	10 Name of Produce and Quantity Declared:
Combretum adenogonium=500 Kgs **Ziziphusspina-christii=500 Kgs**	**Net weight 1,000 Kgs**
11 Botanical Name of Plants: **Combretum adenogonium and Ziziphus spina- christii**	

12 This is to certify that the plants, plant products or other regulated articles described herein have been inspected and or tested according to appropriate procedures and are considered to be free from the quarantine pests specified by the importing contracting party and to confirm with the current phytosanitary requirements of the importing contracting party, including those for regulated non-quarantine pests.

II. ADDITIONAL DECLARATION:

These indigenous tree browses were Inspected and found free from pest & diseases

III. DISINFESTATION AND/OR DISINFECTION TREATMENT

13 Treatment:	14 Duration and Temperature:
Not treated	-
15 Chemical (active ingredient):	16 Concentration:
None	**None**
17 Additional Information:	18 Date:
19 Place of Issue:	20 Name of Authorized Officer:
JUBA, SOUTH SUDAN	**Alexander Ali Natana**
21 Date:	22 Signature of Authorized Officer:
6/12/2016	[signature] Ministry of Agriculture and Food Security MAFS 06 DEC 2016 Republic of South Sudan - Juba

No. 0585540

KP2016585540 2KE

PERMIT No. KEPHIS/3074/2016

REPUBLIC OF KENYA

MINISTRY OF AGRICULTURE & RURAL DEVELOPMENT

KENYA PLANT HEALTH INSPECTORATE SERVICE (KEPHIS)

PLANT IMPORTATION PERMIT

(Plant Protection Act Cap 324) Date 20 September, 2016

The importer must furnish the supplier with a copy of this import permit before plant material is despatched.

*Permission is hereby granted to **Dr. James O. Ondieki, egerton University, Animal Science Dept.**

of **P>O Box 536-20115, EGERTON, KENYA**

to import from **JOHN LORO,, JUBA,, SOUTH SUDAN**

the following **FOLIAGE**

500 KGS COMBRETUM COMBRETUMADENOGONIUM

500 KGS ZIZYPHUS SPINA- CHRISTII

subject to the following conditions

1) All **All Parts** to be the produce of and grown in **SUDAN**
2) The consignment to be inspected on arrival and the importing authority reserves the right to treat, destroy or refuse the importation.
3) Plants or plantparts must be entirely free from soil, chaff and/or leaf mould.
4) Each consignment shall be accompanied by an original copy of this import permit and Phytosanitary Certificate (International Model or its equivalent) from country of origin;

Additional Declarations:

Permit shall include the following conditions:-

(a) Phytosanitary Certificate (International model or its equivalen

(b) Additional conditions as follows:-

(i) The plants were inspected during active growth and found to be free from injurous pests and pathogens.

ii) Foliage to be used for research purposes only in conrolled environment

(N. B. Details to be stated on the Phytosanitary Certificate).

Failure to furnish the required certificates may result in prohibition of entry of the plant materials.

5) **Packaging** The following materials must **not** be used: banana leaves, maize, rice, sorghum, palm, wheat straw soil or leaf mould. If any other plant residue is used as packaging material, the consignment must be accompanied by a certificate stating: all seeds, pathogens and insects have been killed before use of the material either by heating to 180°F / 83°C for ten minutes or by chemical treatment (N.B.- Details to be stated on Phytosanitary Certificate).

This permit is valid for six months from date of issue, but may be cancelled at any time by the Director of Agriculture or by the officer issuing the permit on his behalf

Official Stamp

(NAKURU) 20 SEP 2016

ISABELLA ONDABU

(Signed) ....

for Director of Agriculture

"Import of genetically modified material will require clearance from the National Biosafety Authority in compliance with the Biosafety Act"

The permission hereby granted is additional to any permission or licence required under any other law.

Full name and address of supplier to be stated