

**EVALUATION OF NUTRITIVE VALUE OF BROWSE TREE
FODDER SPECIES INDIGENOUS TO KITETO AND KONGWA
DISTRICTS**

By

Zahara Nassoro

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree
of Master of Science in Biodiversity Conservation of the University of Dodoma

The University of Dodoma

October, 2014

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the University of Dodoma dissertation entitled “*Evaluation of Nutritive Value of Browse tree fodder species indigenous to Kiteto and Kongwa districts*” in partial fulfillment of the requirements for the degree of Master of Science in Biodiversity Conservation of the University of Dodoma.

.....

Dr. Chrispinus D.K. Rubanza

(SUPERVISOR)

Date.....

Dr. Anthony Kimaro

(CO -SUPERVISOR)

Date.....

DECLARATION

AND

COPYRIGHT

I, **Zahara Nassoro**, declare that this dissertation is my own original work and that it has not been presented and will not be presented to any other university for a similar or any other degree award.

Signature.....

No part of this dissertation may be reproduced, stored in any retrieval system, or transmitted in any form or by any means without prior written permission of the author or the University of Dodoma.

ACKNOWLEDGEMENTS

Glory is to the almighty Allah (the gracious, the merciful) for the generous blessings and guidance offered to me during my research work and throughout my entire life at large.

I would like to register my hearty felt thanks to several people who supported me physically and morally to make this study successful.

My supervisors Dr C.D.K Rubanza and Dr Anthony Kimaro deserve my highest gratitude. Their immeasurable guidance, critiques, challenges and advice have led to the accomplishment of this research work.

I would also like to present my sincere appreciation to the International Centre for Research in Agroforestry (ICRAF) for financial support during the research.

I owe my sincere gratitude to the field technicians, Agricultural officers and farmers/livestock keepers in both Kiteto and Kongwa districts for assisting me in identifying and collecting samples of browse tree fodder species commonly fed to ruminant livestock in the area. Special thanks go to Mr.Mtoi, Anna Kiria and Ms.Lioba.

NARCO staffs are greatly acknowledged through the provision of study site and permission for browse sample collection and their temporary storage.

I am very grateful to the laboratory technicians at the Sokoine University of Agriculture and Tanzania Livestock Research Institute (TALIRI) particularly Mr.Malale and Mr. Anderson for processing and chemical analysis of the browse samples. I wish to thank Imam of Masjid Alghazaal in Mpwapwa for welcoming and directing me to get accommodation in one of the hotels during my five days stay in TALIRI for the dry season sample analysis. I express my gratitude to the staffs under the department of Biological Sciences of the University of Dodoma. Special thanks go to the lecturers who conducted MSc Biodiversity Conservation course.

Fellow Masters Students through their advice and cooperation during the course work and research are gratefully appreciated.

The family of Mr. Malik Mliwa is also acknowledged for their kindness, love and support they offered to me throughout my Masters programme, forgetting not to mention my beloved sister in law Mwajuma Malik.

I extend my cordial gratitude to my parents, brothers, sisters, relatives and friends for their material and moral support. Brother Mkanachi, Mabubu, Mtumwa and Jabir Chwaya should be mentioned.

The contribution of my family to the success of this work is not quantifiable. Their tolerance during my absence and their prayers has led to this fruitful dissertation. I owe this special thanks to my young sister Kulthum Masoud for taking care of my children tirelessly during my Masters programme regardless the difficulties and challenges she went through as she is also a university student.

Lastly to my beloved husband Omar Msumba for his love, endless encouragement and support throughout my study. I have no much beautiful words to express my sincere appreciation to him for his immeasurable tolerance during frustrating moments of my Masters program as well as missing his beloved wife and the delicious coastal dishes she used to prepare for him. Thank you and may the Almighty Allah bless you.

DEDICATION

This work is dedicated to my late mother Halima Suleiman, my father Nassoro Mkwayu, my mother in law Hawa Saidi. I also dedicate it to my beloved husband Omar Msumba, my beautiful daughters Sumayyah and Buthaynah forgetting not to mention my one and only son Ammaar.

ABSTRACT

The use of browse tree fodder as supplements to ruminant feeding in the tropics is limited by lack of information on their nutritive potential. A study was carried out to screen eight browse species in Kongwa and Kiteto districts (*Acacia mellifera*, *Acacia senegal*, *Acacia xanthophloea*, *Acacia tortilis*, *Boscia* spp., *Gliricidia sepium*, *Leucaena pallida* and *Melia azedarach*) for potential chemical composition, concentration of minerals, and *in vitro* digestibility potential using chemical assays. Data analysis was done by using SAS (9.1.3) software. Results reveal that the browse tree species had high levels of crude protein (CP) that varied ($P<0.05$) among the species from 130-230 g/kg DM for *A. xanthophloea* and *G. sepium* respectively. The species had moderate to low ($P<0.05$) contents of fibers which varied among the species. NDF ranged from 342 (*Acacia xanthophloea*) to 644 g/kg DM (*Boscia* spp.), ADF 184 g/kg DM (*L. pallida*) to 577 g/kg DM (*M. azedarach*) and ADL ranged from 38-175 g/kg DM. The browse species had sufficient contents of macro minerals which varied ($P<0.05$) among the species from (2.2-12.6, 1.8-7.1, 1.4-6.4 and 1.5-3.1) g/kg DM for Ca, P, Mg and S respectively. Concentrations of micro minerals among the species were moderate to high ($P<0.05$) which varied from (4.3-53, 155-300, 13.1-80.9 and 15.2-46) mg/kg DM for Cu, Fe, Mn and Zn, respectively. The species had high ($P<0.05$) *in vitro* digestibility potential that varied from 320-671 g/kg DM and 325-658 g/kg DM for IVOMD and IVDMD, respectively. The browse tree fodder species in the current study could be utilized as protein supplements to ruminant livestock fed on low quality feeds including hays, stovers and crop residues due to their high levels of crude protein and minerals, low fiber contents as well as high digestibility potential.

TABLE OF CONTENTS

CERTIFICATION	i
DECLARATION AND COPYRIGHT	ii
ACKNOWLEDGEMENTS	iii
DEDICATION	v
ABSTRACT	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF PLATES	xii
ABBREVIATIONS AND ACRONYMS	xiii
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background information	2
1.2 Statement of the problem	5
1.3 Objectives of the study	7
1.3.1 General objective	7
1.3.2 Specific objectives	7
1.4 Hypotheses	7
1.5 Significance of the study	8
1.6 Scope of the study	8
CHAPTER TWO	9
LITERATURE REVIEW	9
2.1.1 Definition of key terms.....	9
2.1.2 Theories underlying the study	12
2.2 Empirical literature review	14
2.2.1 Nutritive value of forages	14
2.2.1 Chemical composition of forages	14
2.2.2 Concentration of minerals	15
2.2.2 Factors affecting forage chemical composition.....	18
2.2.2.1 Influence of genotype on chemical composition of forages.....	18

2.2.2.3 Influence of stage of growth on feed chemical composition.....	19
2.2.2.3.4 Influence of soil on Chemical composition.....	19
2.2.2.6 Influence of anti-nutrient factors on chemical composition.....	20
2.3 Intake of browse tree foliages	20
2.3.1 Factors affecting feed intake.....	21
2.4 Digestibility of the browse tree foliages.....	23
2.5 Feed evaluation techniques	26
2.5.1 Chemical composition	26
2.5.3.1 <i>In vitro</i> digestibility	27
2.5.3.2 Two stages <i>in vitro</i> digestibility	27
2.7 Research gap	28
2.8 Conceptual Framework	28
2.8.1 Independent variables	28
2.8.2 Intermediate variables.....	29
2.8.3 Dependent variables	30
CHAPTER THREE	31
RESEARCH METHODOLOGY	31
3.1 Study site	31
3.1.1 Location	31
3.1.2 Climate.....	31
3.1.3 Vegetation.....	32
3.2 Experimental design.....	33
3.2.1 Collection of samples	33
3.3 Laboratory analyses.....	34
3.3.1 Dry matter content	34
3.3.2 Ash content	34
3.3.3 Crude protein	34
3.3.4 Dietary fibers analysis	35
3.5 <i>In vitro</i> digestibility potential.....	37
3.7 Data processing and analysis.....	38

CHAPTER FOUR.....	40
DATA PRESENTATION, ANALYSIS AND DISCUSSION OF THE	
FINDINGS	40
4.1 Results	40
4.1.1 Chemical composition	40
4.1.2 <i>In vitro</i> digestibility	45
4.1.3 Concentration of minerals	50
4.2 Discussion of findings	52
4.2.1 Chemical composition.....	52
4.2.2 <i>In vitro</i> digestibility	54
4.2.3 Macro minerals	55
4.2.4 Micro minerals.....	56
CHAPTER FIVE	58
SUMMARY, CONCLUSIONS AND AREAS FOR FURTHER STUDY	58
5.1 Summary of the main findings	58
5.2 Conclusion.....	60
5.3 Recommendations	60
5.4 Areas for further study	61
REFERENCES.....	62

LIST OF TABLES

Table 1: Chemical composition (g/kg DM) of common browse fodder species	17
Table 2: Suggested mineral requirements for ruminants	18
Table 3: In vitro organic matter digestibility potential (IVOMD) of selected browse legume species (g/kg DM).....	25
Table 4: Table 3: In vitro organic matter digestibility potential (IVOMD) of selected browse legume species (g/kg DM). <i>In vitro</i> dry matter digestibility potential of common browse species (g/kg DM).....	25
Table 5: Chemical composition (g/kg DM) of leaves of selected browse tree fodder species indigenous to Kongwa and Kiteto districts	41
Table 6: In vitro digestibility potential (g/kg DM) of the selected browse foliage species indigenous to Kongwa and Kiteto districts for dry and wet seasons	45
Table 7: Concentration of macro minerals (g/kg DM) of the selected browse species in Kongwa and Kiteto districts.	48
Table 8: Concentration of micro minerals (mg/kg DM) of the selected browse species in Kongwa and Kiteto districts.....	49

LIST OF FIGURES

Figure 1: Conceptual framework.	30
Figure 2: A map of Kongwa and Kiteto districts showing the study sites.....	32

LIST OF PLATES

Plate1. <i>Acacia xanthophloea</i> sample collected from Kibaya, Kiteto.....	36
Plate 2: Determination of chemical composition.....	36
Plate 3: Collecting and filtering rumen liquor from a fistulated cow.	38
Plate 4: Samples mixed with rumen liquor and artificial saliva being incubated.....	38

ABBREVIATIONS AND ACRONYMS

ADF	Acid detergent fiber
ADL	Acid detergent Lignin
ANFs	Anti nutrient factors
ANOVA	Analysis of variance
CF	Crude fiber
CP	Crude protein
CT	Condensed tannins
Ca	Calcium
DDM	Digestible dry matter
DM	Dry matter
DMD	Dry matter digestibility
DMI	Dry matter intake
DOM	Digestible organic matter
EE	Ether extract
Fe	Iron
ICRAF	World Agroforestry Centre
g	gram
IVDMD	<i>in vitro</i> dry matter digestibility
IVOMD	<i>in vitro</i> organic matter digestibility
K	Potassium
Kg	Kilogram
Mg	Magnesium
Mn	Manganese
N	Nitrogen

NARCO	National Ranching Company
NDF	Neutral detergent fiber
NDFD	Neutral detergent fiber digestibility
NFE	Nitrogen free extract
NIRS	Near Infra-red Reflectance Spectroscopy
⁰ C	Degrees centigrade
⁰ E	Degrees East longitudes
OM	Organic matter
OMD	Organic matter digestibility
PA	Proanthocyanidins
PEG	Polyethylene glycol
S	Sulfur
S	Degrees South latitudes
SAS	Statistical Analytical System
Spp.	Species
SUA	Sokoine University of Agriculture
TCT	Total condensed tannins
TEP	Total extractable phenolics
TET	Total extractable tannins

CHAPTER ONE

INTRODUCTION

Enhanced livestock productivity (growth rate, milk production, meat, draft power, reproductive efficiency, conception rate, and calving interval) is limited by poor feeding and nutrition with the dry season being the most limiting. Livestock production in the tropical region including Tanzania is limited by feed scarcity in terms of both quantity (biomass) and quality in with protein or crude protein (CP) being the most limiting nutrient (Leng, 1990) in addition to energy. In Tanzania, livestock production is an important economic activity especially in rural areas mainly based on traditional production system with a limited number being under commercial farming system. Agro pastoralists in many arid and semi-arid regions of the world including Kongwa district of central Tanzania and Kiteto district of north eastern Tanzania rely on low quality forages mainly standing hay and crop residues such as stovers, straw and chuffs for feeding their livestock especially during dry seasons (Rubanza, 2013). Utilization of these feeds is limited by their inherent low quality in terms of nutrients which has been associated with low animal productivity in terms of growth, meat, milk, work, poor reproductive efficiencies (silent heat, low conception rates, high number of mating per conception, long calving intervals) (Kanuya *et al.*, 2006).

Browse tree fodder species such as *Acacia* spp. are better in terms of nutrient content especially crude protein (CP) ranging from 100-250 g/kg DM (Abdulrazak *et al.*, 2000; Rubanza *et al.*, 2005; Rubanza *et al.*, 2006). The browse feeds are normally used as protein supplements in a wide range of ruminants (Kakengi *et al.*, 2001; Shem and Machibula, 2002; Rubanza *et al.*, 2007) by either being direct browsed by

both wild ungulates and domestic animals in the range or being fed to the animals or being cut and fed to the livestock under the typical 'cut and carry'. However, less is known on nutritive potential of browse fodder species in semi-arid areas of the world such as Kongwa and Kiteto districts. The current study was carried out to assess nutritive values of selected browse tree species foliages through chemical composition (both conventional chemical composition analyses and minerals), and *in vitro* digestibility of four *Acacia* spp. (*A. mellifera*, *A. senegal*, *A. tortilis*, *A. xanthophloea*), *Boscia* spp., *M. azedrach* and other two important fodder species (*G. sepium* and *L. pallida*) that were used as reference species based on nutritional superiority.

1.1 Background information

Ruminant livestock productivity in semi-arid areas of Tanzania including Kongwa and Kiteto districts is mainly constrained by dry season feed shortages with protein, minerals and energy being the most limiting. The chief feed resources are natural pastures and crop residues (Rubanza, 2013) that are very low in crude protein (CP) ranging between 30 to 50 g/kg DM (Leng, 1990), low digestibility potential as well as low concentration of minerals (Leng, 1997). The pasture could be sufficient during the rainy season as opposed to dry season which is normally accompanied by persistent feed shortages. However, sustainable animal production from pastures is constrained by the rapid decrease in nutritive value with advancement in forage maturity (Crowder and Cheddah, 1982). Poor animal performance in the dry season is largely explained by the lack of protein, energy, minerals (Le Houérou, 1980; McDowell *et al.*, 1983). According to Crowder and Cheddah (1982), concentration of CP mature grasses declines to 1-2 % during the dry season. Forage maturity is associated with increased extent of fiber build up and lignifications that are largely

associated with decreased feed digestibility (Fonseca *et al.*, 1998) and thus poor nutrient utilization. Such fluctuating nutrient pattern along seasons has been associated with fluctuating animal production of the grazing herd. Impact of feed shortages would be much more pronounced in areas with large concentration of livestock and in particular due to the typical low carrying capacity of most grazing lands and the pressure exerted by high stocking densities.

Livestock population in Tanzania is estimated to 21.3 million cattle, 15.2 million goats, 6.4 million sheep, 1.9 million pigs, 35 million traditional chickens and 23 million layers and broilers (URT, Livestock Sample Survey Census, 2011). The most common livestock feeding systems in semi-arid areas include grazing, partial grazing with minimal supplementation, stall feeding or zero grazing and tethering (Williamson and Payne, 1990). However, variability on livestock management systems and in particular cattle management exists at global, regional, national and local scales (Williamson and Payne, 1990), mainly depending on the predominant land use systems. In many semi-arid areas including Tanzania, applicable livestock grazing management depends on the existing rangeland resource and the associated land uses/ competition.

Variable livestock management practices exist in Kongwa and Kiteto districts. In Kongwa district of Central Tanzania during dry seasons livestock keepers graze their herds on crop residues mainly maize and sorghum stovers as compared to wet seasons when the agro pastoralists temporarily transfer their herds to distant pastures on hilly and mountain areas where there is less cropping (Rubanza, 2013). In Kiteto district in contrast, some agro pastoralists especially those in northern parts of the district, mainly the Maasai ethnic group, practice an *in situ* vegetation conservation

system, traditionally referred to as '*Allele*' (Rubanza, 2013). Under '*Alalili*' livestock grazing management system, during wet seasons, livestock are grazed on distant pastures where there is less cropping. During the dry seasons, livestock are grazed on these silvo pastoral traditional fodder banks that are normally set to offset feed shortages during dry seasons (Rubanza, 2013). The *Alalili* grazing management system is comparable to other silvo pastoral fodder technologies among many ethnic groups of Tanzania (Rubanza, 1998) such as the *Ngitili* system of north western Tanzania (Rubanza, 1999; Mlinge, 2004, Rubanza *et al.*, 2014) as well as other East African countries.

The use traditional rangeland management systems such as reserving areas with pasture during wet season for use during dry season overcome acute dry seasons feed shortages is comparable to *Ngitili* agro silvo pastoral technology practiced by Sukuma pastoralists in Shinyanga and Mwanza regions (Rubanza *et al.*, 2014). The *Alalili* system is similarly comparable to *Kibawoo* silvo pastoral fodder banks of Rangi ethnic groups of Kondoa district in semi- arid parts of Tanzania (Rubanza, 1998). However, livestock production from these silvo pastoral fodder banks vary greatly across seasons with relatively good production during wet seasons when there is bulky feed resources with relatively promising nutrients (protein, carbohydrates and minerals). On the other hand, livestock production in many semi-arid areas including Tanzania is marked by rapid decline in productivity (growth, milk, meat, and reduced reproductive efficiency) mainly due to feed deficit in terms of protein or crude protein (CP) which drops to as low as 30-50 g/kg DM (Rubanza, 1999) thus necessitating for supplementation. Fodder from browse trees and shrubs represent potential supplements due to their high CP content of 100-250 g/kg DM (Le Houéou, 1980; Abdulrazak *et al.*, 2000a, b; Rubanza *et al.*, 2003a, b; Rubanza *et*

al., 2005a, b). The browse feeds supply deficient nutrients, mainly nitrogen or crude protein (CP), energy and minerals, in the basal feeds (*i.e.*, standing hay, stovers and straw) during regular feed shortages and droughts (Melagu *et al.*, 2003; Kumara *et al.*, 2009). However, optimal utilization of browse tree species as important feed resources mainly to supplement low quality forages could be limited by little available information on nutritive value profile of browse tree species native to Kongwa and Kiteto districts. The current study was therefore carried out to assess chemical composition and *in vitro* digestibility of four *Acacia* spp. (*A. mellifera*, *A. senegal*, *A. tortilis*, *A. xanthophloea*), *Boscia* spp., *Melia azedarach*, *Gliricidia sepium*, *Leucaena pallida* indigenous to Kongwa and Kiteto districts.

1.2 Statement of the problem

Livestock production of many semi-arid areas of the world including Kongwa district of Central Tanzania and Kiteto district of north eastern Tanzania is characterized by low reproductive performance, low milk yield and low growth rates that are associated with poor nutrient quality of feeds (Le Houérou, 1980; Rubanza *et al.*, 2005). Indigenous browse foliage species such as *Acacia* spp. and other browse fodder species serve as cheap sources of nitrogen (N) or crude protein (CP) and minerals and are thus used as supplements to diets of low quality including crop residues and standing hays that are normally fed to ruminants (Rubanza, 2005; Rubanza *et al.*, 2007). Browse tree and shrub foliages (*i.e.*, leaves, twigs, pods, fruits, barks and soft tender stems) represent cheap sources of protein due to their high CP of 100-250 g/kg DM, (Le Houérou, 1980; Abdulrazak *et al.*, 2000; Rubanza *et al.*, 2003a, b; Rubanza, 2005; Rubanza *et al.*, 2005a, b; Rubanza *et al.*, 2007). The browse tree foliages of different species have therefore been used as CP supplements to ruminants fed on low quality basal roughages such as hay, stovers and straws

(Rubanza *et al.*, 2007) that represent bulk feed resources in arid and semi-arid regions of the world including Africa and Tanzania in particular and throughout the tropics (Leng,1990). Available information on nutritive value of tree fodder species is limited to chemical composition and minerals (Le Hou  rou, 1980). Similarly, optimal utilization of feed protein from browse feed is limited by their inherent high levels plant secondary metabolites such as phenolics and tannins that act as feed anti-nutrient factors (ANFs) due to their effects on poor nutrient utilization in ruminants. Available information on nutritive potential of browse tree and shrub species native to semi-arid areas of Tanzania is limited to *Acacia* spp. such as *A. drepanolobium*, *A. nilotica*, *A. polyacantha*, *A. nubica*, *A. senegal* (Abdulrazak *et al.*, 200a, b) as well as other browse species such as *Dichrostachys cinerea*, *Flagea villosa*, *Harrisonia abyssinica* and *Piliostigma thorningii* (Rubanza *et al.*, 2003a) and some *Acacia* spp. (*A.drepanolobium*, *A. nilotica*, *A. polyacantha*, *A. senegal* *A. tortilis*), (Rubanza *et al.*, 2003b; Rubanza *et al.*, 2005a, b).

The current study was intended to determine feed potential in terms of chemical composition and *in vitro* digestibility of selected four species of *Acacia* (*A. mellifera*, *A. senegal*, *A. tortilis*, *A. xanthophloea*), *Boscia* spp., *Melia azedarach* indigenous to Kongwa and Kiteto districts of Tanzania compared to *Gliricidia sepium*, *Leucaena pallida* that were used as reference feeds due to their well established nutritional profiles (Kakengi, 1998; Rubanza, 1999; Kakengi *et al.*, 2001; Shem and Machibula, 2002; Rubanza, 2005; Rubanza *et al.*, 2005c; Rubanza *et al.*, 2007).

1.3 Objectives of the study

1.3.1 General objective

The general objective underlying the current study was to characterize nutritive potential in terms of ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) as well as *in vitro* digestibility using rumen liquor of selected browse tree foliage species indigenous to Kongwa and Kiteto districts.

1.3.2 Specific objectives

- i. To determine chemical composition of browse fodder species in terms of ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and concentration of macro and micro minerals, and
- ii. To determine *in vitro* digestibility potential in terms of *in vitro* organic matter digestibility (IVOMD) and *in vitro* dry matter digestibility (IVDMD).

1.4 Hypotheses

The study was guided by the following hypotheses:

- i. Browse tree foliage-based diets for ruminant livestock are characterized by high contents of ash, crude protein, neutral detergent fiber, low contents of acid detergent fiber and acid detergent lignin.
- ii. Browse tree foliages have high concentrations of macro and micro minerals, and
- iii. Browse tree foliages are characterized by high feed digestibility potential.

1.5 Significance of the study

Findings presented in the current study serve as part of body of knowledge and provide necessary information related to nutritive value of browse tree foliage- based feed resources commonly fed to ruminant livestock. Generated data in the current report contribute on strategies towards improved livestock management among agro pastoral communities by improving livestock feeding efficiency and thus enhanced livestock productivity by enhancing livestock supplementation using cheap locally available protein or CP supplements such as browse tree foliages. Findings from the current study provide baseline data for further studies as related to improved ruminant feeding and nutrition across a wide range of livestock stakeholders at local, national, regional and international scales.

1.6 Scope of the study

The current study focused on determining chemical composition in terms of conventional analyses for ash, crude protein, neutral detergent fiber, acid detergent fiber, acid detergent lignin and minerals (both macro and micro minerals). The feeds were similarly assessed for their digestibility potential through *in vitro* organic matter digestibility (IVOMD) and *in vitro* dry matter digestibility (IVDMD) of selected four *Acacia* spp. (*A. mellifera*, *A. senegal*, *A. tortilis*, *A. xanthophloea*) and *Boscia* spp. commonly found in semi-arid rangelands, and *Melia azedarach*, a promising exotic fodder species commonly integrated in many agro forest systems such as woodlots, boundary tree planting and fodder banks compared to two reference browse fodder species (*Gliricidia sepium* and *Leucaena pallida*) whose nutritive values have been widely documented (Norton, 1998; Shem and Machibula, 2002).

CHAPTER TWO

LITERATURE REVIEW

This chapter provides the definitions of key terms, theories and empirical literature review from other studies based on evaluation of nutritive value of browse fodder species in semi-arid areas of Tanzania, Africa and the World at large. The chapter aims at finding out what other researchers have done as far as this study is concerned, identifying the research gap and finally providing conceptual framework for the study.

2.1 Theoretical literature review

2.1.1 Definition of key terms

2.1.1.1 Nutritive value

Nutritive value of forages refers to its chemical composition, intake, digestibility and utilization of absorbed food and nature of the digested products. The quality of forages is determined in terms of chemical composition, digestibility of plant constituents and amount of feeds consumed by ruminants. However, the total amount of the forage materials eaten by animal is an important factor upon animal response as it affects total intake of nutrients (Crowder and Cheddah, 1982).

2.1.1.2 Anti-nutritive factors

Plants produce chemicals that are not directly involved in the process of plant growth, but act as deterrents to insect and fungal attack (Norton, 1994). Thus in some plants, the utility of leaves, pods and edible twigs of shrubs and trees as animal feeds is limited by the presence of feed anti-nutritional factors (ANFs). Feed anti-nutritional factors are defined as those substances generated in natural feedstuffs by

the normal metabolism of species and by different mechanisms (example, inactivation of some nutrients, diminution of the digestive process or metabolic utilization of feed) which exert effect contrary to optimum nutrition (Kumar, 1992). The effects of ANFs vary with plant species, animal species and stage of growth. Non-ruminants (pigs, poultry, and horses) are usually more susceptible to toxicity than ruminants. Examples of feed anti-nutritive factors include tannins, oxalates, saponins, cyanides (Reed *et al.*, 1990; Tanner *et al.*, 1990).

2.1.1.3 Tannins

Tannins are defined as naturally occurring polyphenolic compounds of high enough molecular weight (500-3000 Daltons) to form complexes with protein (Mangan, 1988). Tannins are classified into two groups based on their structural types: hydrolysable tannins composed of polyhydroxyl alcohol esterified with gallic or ellagic acid, and condensed tannins which are flavonoid based polymers (Makkar, 2000). Most African browse tree foliages have high levels of phenolics and tannins ranging from 10-50% DM (Abdulrazak *et al.*, 2000; Rubanza *et al.*, 2003; Mlambo *et al.*, 2004; Rubanza *et al.*, 2005). Deleterious effects of tannins include inhibition of digestive enzymes and toxic effects on rumen microbes (Osuji and Odenyo, 1997; Brooker *et al.*, 1998). However, phenolics and tannins when present at low levels (less than 5%) are beneficial as they act as plant secondary metabolites and protect proteins from rumen degradation (Aerts *et al.*, 1999).

2.1.1.4 Digestibility

Digestibility of a feed is defined as that proportion which is not excreted by in the faeces and which is therefore assumed to be absorbed by the animal. It is commonly

expressed in terms of dry matter and as a coefficient or a percentage. The general formula for calculation of digestibility coefficients is:

$$\text{Digestibility} = \frac{\text{Nutrient consumed} - \text{Nutrient in faeces}}{\text{Nutrient consumed}} \text{ (McDonald } et al., 1995).$$

Digestibility is a measure used to describe the nutritive value of forages and determine the quality of feeds in relation to its chemical constituents (Dynes and Schlink, 2002). Digestibility of plant material is related to the proportion of lignin in cell walls of the plant (Van Soest *et al.*, 1991).

2.1.1.5 *In vitro* digestibility

Oba and Allen, (2005) defined *in vitro* digestibility as a laboratory technique used for determination of digestibility of feed stuffs by simulating rumen environment and its digestive juices. However, In addition, *in vitro* estimations of feed degradation are important tools for ruminant nutritionists as it can be used to evaluate quality of feed with the regard of their nutritive values (Kamalak *et al.*, 2004). *In vitro* methods have the advantage not only of being less expensive and less time- consuming, but they allow one to maintain experimental conditions more precisely than do *in vivo* trials (Getachew *et al.*, 1998).

2.1.1.6 *In sacco* digestibility

In sacco digestibility, also named as nylon bag or *in situ*, is an evaluation technique based on depositing separately foodstuff into bags which are incubated into the rumen of an animal fitted with a rumen cannula (Ørskov and McDonald, 1979). The technique aims to measure the disappearance of dry matter and/or other nutrients such as crude protein, fiber fraction and even mineral from food sample under

concern at different time intervals: 0, 3, 6, 8, 12, 16, 24, 36, 76 and 96 h (Ørskov and McDonald, 1979).

2.1.2 Theories underlying the study

This section provides the theoretical framework for the study based on two theories: Optimal foraging theory and Predator –prey theory.

2.1.2.1 Optimal foraging theory

Optimal foraging theory is a concept in ecology based on the study of foraging behavior and states that “organisms forage in such a way as to maximize their net energy intake per unit time”. In other words, they behave in such a way as to find, capture and consume food containing the most calories while expending the least amount of time possible in doing so (Pike *et al.*, 1977). Optimal foraging theory thus predicts that the animal will first consume food items with the highest ratio of food value to time and energy spent in searching for and handling the food item. The animal will always seek the highest ranked foods available, and when the food items of the highest rank are depleted, foods will be added on to the diet in their rank order (Pike *et al.*, 1977).

Large herbivores make foraging decisions hierarchically, in scales from region, landscape, plant community, foraging path and, plant-to-plant module taken in the single bite (Pastor *et al.*, 1997; Skarpe *et al.*, 2000). According to optimal foraging theory (Pyke *et al.*, 1977, a foraging animal makes the following four interdependent decisions: which patch type to visit; how long to stay in each patch; which food types to eat in the patch and which foraging path to employ in the patch. Grazing animals compose their diets by differentiating between plant species and plant parts

that vary in nutritional value and in chemical and mechanical defence (Provenza and Balph, 1988).

Morphological characteristics, such as spines and thorns, often affect the foraging behaviour of grazing animals (Cooper and Owen-Smith, 1986) as well as content of various deterring compounds (Cooper and Owen-Smith 1985). Likewise, grazing animals mainly select biomass with high proportion of leaves and low proportion of stem, as leaves have higher nutritive value. Thus they will largely reject tall, mature pasture.

2.1.2.2 Predator - prey theory

Predation is used here to include all positive and negative interactions in which one organism consumes all or part of another. This includes herbivore-plant, and parasite-host interactions and even predator- prey relationship in carnivore scenarios (Gotelli, 1995). Predator-prey theory explains the cyclic interaction or the relationship between herbivores and plants. When prey (plants) are numerous their predators (herbivores) increase in numbers, reducing the prey population, which in turn causes predator number to decline (Gotelli, 1995). The prey population eventually recovers, starting a new cycle. This suggests that the population of the herbivore fluctuates around the carrying capacity of the food source, in this case the plant. Several factors play into these fluctuating populations and help stabilize predator-prey dynamics. Spatial heterogeneity is maintained, which means there will always be pockets of plants not found by herbivores. This stabilizing dynamic plays an especially important role for specialist herbivores that feed on one species of plant and prevents these specialists from wiping out their food source. Prey defences, for example, the presence of spines in some plants also help to stabilize predator-

prey dynamics. Eating a second prey type helps herbivores' populations stabilize (Smith *et al.*, 2001). Alternating between two or more plant types provides population stability for the herbivore, while the populations of the plants oscillate (Smith *et al.*, 2001).

2.2 Empirical literature review

This part presents experiences, approaches and lessons learnt from other researchers who worked on evaluating nutritive value of browse tree fodder species for ruminant livestock. The review considers various experiences learnt at local, regional and global levels.

2.2.1 Nutritive value of forages

According to Crowder and Cheddah (1982), nutritive value of forages refers to its chemical composition, intake, digestibility and utilization of absorbed food and nature of the digested products. The latter authors reported that, quality of forages is determined in terms of chemical composition, digestibility of plant constituents and amount of feeds consumed by ruminants. However, the total amount of the forage materials eaten by animal is an important factor upon animal response as it affects total intake of nutrients and subsequently influences animal production.

2.2.1 Chemical composition of forages

Results demonstrated in different literature show variable chemical composition among various browse fodder species ranging from 35-60, 107-300, 154-511, 14-396 and 51-206 g/kg DM, for ash, crude protein(CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin(ADL), respectively (Sawe *et al.*,1998; Abdulrazak *et al.*, 2000a,b; Rubanza *et al.*, 2003a,b).

Most browse foliage species in the literature contain medium to high concentrations of crude protein ranging from 120 to 292 g/kg DM (Reed *et al.*, 1990; Abdulrazak *et al.*, 2000a, b; Mokoboki *et al.*, 2006). The high CP values of browse tree and shrub legumes suggest their potential as CP supplements to ruminants fed at low quality roughages. Tropical grasses especially during dry season or at maturity contain low CP which is lower than the minimum CP requirements of 80 g/kg DM (Annison and Bryden, 1998).

Neutral detergent fiber (NDF) is considered to be an acceptable measure of the partially digestible cell wall contents, but this also varies in amount between species and ranges from 154 to 619 g/kg DM (Topps, 1992; Mtengeti *et al.*, 2006). Van Soest (1994) reported that NDF for forage species ranges from 540 to 770 g/kg DM. Increasing levels of NDF limits dry matter intake. Most browse tree foliage species have moderate to low contents of fibers. Mokoboki *et al* 2011 reported low ADF for *Acacia hebeclada* (145 g/kg DM) and *Acacia siberiana* (165 g/kg DM) which could be associated with high digestibility. Mtui *et al.* (2009) reported low ADL which ranged from 33 g/kg DM (*Morus alba*) to 110g/kg DM (*Gliricidia sepium*). The chemical composition of common browse fodder species is shown in Table 1.

2.2.2 Concentration of minerals

Minerals are necessary for normal growth, reproduction, health and proper functioning of the animal's body (McDowell, 1992). Minerals protect and maintain the structural components of the body, organs and tissues, and are constituents of body fluids and tissues as electrolytes. Minerals have catalytic functions in the cells

as well as maintaining acid-base balance and osmotic control of water distribution within the body (McDonald *et al.*, 1995).

2.2.2.1 Macro minerals.

Most of tropical legumes contain Ca levels ranging from 8.6-10.2 g/kg DM (Minson, 1990); Rubanza. (2005); Rubanza *et al.* (2006) and Mtui *et al.* (2008) reported a high range of Ca (6.6-35.6) g/kg DM. Ca: P ratio recommended for normal physiological function of ruminants is 2:1 (McDonald *et al.*,1995). Browse species in most cases have much higher Ca: P than the requirements of the animal such as that reported by Rubanza, 2005 (6.6:1-31.5:1) and Rubanza *et al* (13.8:1-55.1:1). Phosphorus levels for most browse species range from 1-5 g/kg DM as noted by Rubanza *et al.* (2006), Mtengeti *et al* (2006) and Mtui *et al* 2008). However Abdulrazak *et al.*(2000) noted low P concentrations in *Acacia* species ranging from 0.7-1.6 g/kg DM. Magnesium concentrations in browse species in most legumes have range from 1.3-6.6 g/kg DM (Abdulrazak *et al.*, 2000; Rubanza *et al.*, 2006; Mtengeti *et al.*, 2006 and Mtui *et al.*, 2008). Sulfur contents in *Acacia* species were reported to range from *Acacia brevispica* (0.7 g/kg DM) to *Acacia nubica* (6.6 g/kg DM).

2.2.2.2 Micro minerals

Concentrations of sulfur in most tropical legumes range from 15-35 mg/kg DM (Minson, 1990). Concentrations of Cu reported by Kakengi *et al.* (2007) and Rubanza *et al.* (2006) ranged from 5.1-9.9 mg/kg DM. However, Abdulrazak *et al.* (2000) noted high concentration of Cu for *Acacia senegal*. Rubanza. (2005) reported high contents Fe for tropical browse species which ranged from 146.2-432 mg/kg DM. However, the minimum Fe requirement for ruminants is 30-60 mg/kg DM and

the Fe contents for most tropical forages and legumes range from 100-700 mg/kg DM (McDowell, 1992).

Manganese contents for browse species as reported by Rubanza. (2006) ranged from 44.6-306 mg/kg DM. However Abdulrazak *et al.* (2000) and Kakengi *et al.* (2007) reported a different range (9.4-67.8) mg/kg DM for other browse species. The levels of Zinc in most browse species range from 10.2-34.7 mg/kg DM (Abdulrazak *et al.*, 2000, Rubanza *et al.*, 2006 and Kakengi *et al.*, 2007).Minson (1990) reported mean Zn concentration of most forages ranging from 36-47 mg/kg DM.

Variations in the concentrations of macro and micro minerals among species could be contributed by the difference in nature of soils, soil fertility and mineral status of the soil. Also it may be caused by difference in genotypes, variation of mineral uptake among the species, stage of maturity and proportion of leaf samples taken for analysis (Minson, 1990).

Table 1: Chemical composition (g/kg DM) of common browse fodder species

Browse species	CP	NDF	ADF	ADL	Ash	Literature
<i>Acacia tortilis</i> (fruits)	141	195	169	42	41	Abdulrazak <i>et al</i> (2000).
<i>Acacia tortilis</i> (leaves)	172	296	192	77	n.a	Abdulrazak <i>et al</i> (2000).
<i>Melia azedarach</i>	141	n.a	n.a	n.a	53	Azim (2011).
<i>Acacia senegal</i>	238	245	141	52	77	Abdulrazak <i>et al</i> (2000).
<i>Acacia mellifera</i>	194	269	192	77	n.a	Abdulrazak <i>et al</i> (2000).
<i>Gliricidia sepium</i>	212	455	305	138	n.a	Mtui <i>et al</i> (2009).
<i>Leucaena pallida</i>	218	446	423	126	n.a	Ndlovu <i>et al</i> (2000).
<i>Salvadora persica</i>	184	333	213	71	271	Rubanza <i>et al</i> (2006).
<i>Boscia</i> spp.	231	370	257	93	88	Rubanza <i>et al</i> (2006).
<i>Morus alba</i>	186	246	208	81	143	Shayo (1997).
<i>Acacia hebeclada</i>	226	379	145	n.a	n.a	Mokoboki <i>et al</i> (2011).

n.a means not assayed

Table 2: Suggested mineral requirements for ruminants

Elements	Beef cattle	Sheep	Goats	Reference
Ca%	0.2	0.21-0.52	-	NRC (1984).
P%	0.31-0.40	0.16-0.37	-	NRC (1981).
S%	0.08-0.15	0.14-0.25	0.16-0.32	NRC (1978).
Mg%	0.05-0.70	0.04-0.08	-	NRC (1984).
Cu (ppm)	4-10	0.1	0.1	NRC (1981).
Fe (ppm)	50-100	30-50	-	NRC (1981).
Mn (ppm)	20-50	20-40	>5.5	NRC (1978).
Zn (ppm)	20-40	35-50	>10.0	NRC (1981).

2.2.2 Factors affecting forage chemical composition

Chemical composition of browse tree foliages is a function of species (Crowder and Cheddah, 1982) and environmental factors (Singh *et al*, 2010). Main factors include genotype, stage of growth, edaphic factors, climatic condition, topography and presence of toxic substances.

2.2.2.1 Influence of genotype on chemical composition of forages

Genotypic variations among browse tree species affect chemical composition of the tree forages in relation to nutritional value (Upreti and Shrestha, 2006). Erickson *et al.*, (1982) noted variability in the chemical components among barley straw of different cultivars. The latter authors noted that, six-rowed barley straw had low CP, P and hemicelluloses while higher in neutral detergent fiber (NDF), acid detergent fiber (ADF) and ash compared to two-rowed barley straw. Genotypic differences were also observed between Karl barley straw and six-rowed barley straw genotypes whereby the Karl barley straw had higher nutritive value compared to six –rowed and two-rowed barley straws (Erickson et al, 1982).

2.2.2.3 Influence of stage of growth on feed chemical composition

Chemical compositions of tree foliages are highly affected by plant maturity (Upreti and Shrestha, 2006). Plant growth from seedling to maturity involves different stages including vegetative phase, stem (seedling) and finally reproductive stage. Furthermore, there is continuous change in plant chemical composition as it grows from one stage to another. Younger plants tend to have higher CP contents than matured plants, for instance Singh *et al.* (2010) noted higher levels of crude protein in young leaves of *Celtis australis* which decreased with leaf maturation. Total dry matter yield is linearly related to the plant maturity and inversely related to digestibility. Similarly, Shayo (1997) noted lower concentrations of crude protein in older leaves (140 g/kg DM) than younger leaves (186 g/kg) DM of *Morus alba* in semi- arid areas of Mpwapwa, Dodoma.

2.2.2.3.4 Influence of soil on Chemical composition

Soil texture has a significant effect on fresh biomass yields, dry matter, crude cellulose and crude ash content formation mainly due to its influence on nutrient supply to the plants. Trees grown on light soil texture tend to have high fresh biomass yield, dry matter, crude protein, cellulose and crude ash content formation than those grown on heavy textured soil. (Geren *et al*, 2009). The main effect of soil on feeds nutritive value is related to soil's nutrient status and availability .For instance soil with specific nutrient deficiency reflects in the foliages which could have negative impact on plant productivity (Aikpokpodion, 2010).

2.2.2.6.5 Influence of altitude on chemical composition

Altitude differences influence nutritive variation of tree foliages (Mountousis *et al.*, 2006; Singh *et al*, 2010). Variation in *in vitro* dry matter digestibility was observed

in the study of *Albizia gummifera* due to altitude differences (Kechero and Duguma, 2011). The latter author added that ash, crude fiber (CF) and crude protein content of the browseable materials are much influenced by altitude variations as it showed positive correlation to EE and CF content. The results from the study of *Celtis australis* indicated that high altitudinal populations exhibited comparatively higher nutritive values than those from low altitude. Crude protein in adult foliage also showed strong positive correlation with altitude. However, ash content did not exhibit any established trend with an altitude either in case of adult or juvenile foliages. (Singh *et al*, 2010).

2.2.2.6 Influence of anti-nutrient factors on chemical composition

Tannins as the plant secondary compounds acting as anti-nutritional factors affecting rumen function by reducing rumen ammonia level, decrease protein degradation, depressing fiber digestibility (Mangan, 1988). At low concentration of tannins in the diets of ruminants (less than 5%), tannins play beneficial roles by increasing by-pass protein or by decreasing ammonia loss (Gutteridge and Shelton, 1998; Aerts *et al.*, 1999). At higher concentration of tannins (>50 g/kg DM) tannins cause detrimental effects by depressing palatability, decreasing rumen ammonia and post-ruminal protein absorption and thus lowered protein availability.

2.3 Intake of browse tree foliages

Intake refers to the total quantity of digestible nutrients consumed by an animal (Van Soest, 1982). Normally, animals stop eating when a certain degree of fill is attained (Ørskov and Ryle, 1990). Feed intake in ruminants consuming fibrous feeds is primarily determined by the level of rumen fill, which in turn related to the rate of digestion and passage of fibrous particles from the rumen (Fonseca *et al*, 1998).

Feed intake is a function of feeds characteristics, animals, environment and the interaction among these factors (Ørskov and Ryle, 1990). Feed intake is usually related to feed protein content whereby low protein content in the diet affects its digestibility through reduction of rumen digestion as bacterial growth requirements are not met. However, it is expected that high intake and low feed digestibility may be related to rapid rates of feed passage through the rumen for instance when small leaflets of pinnate leaves are being consumed (Gutteridge and Shelton, 1998).

2.3.1 Factors affecting feed intake

Animals are capable to feed on and digest different types of feedstuffs although feeding efficiency is reduced by some plant or animal related factors (Gutteridge and Shelton, 1998). Factors affecting feed intake includes animal factors and plant related factors.

2.3.1.1 Animal factors

Physiological state of the particular animal influences the intake of feed. For instance young and older animals tend to have high intake of feeds for better growth and restore depleted body tissue, respectively (Shipley and Felicetti, 2002). Furthermore, high rate On the other hand, some physiology activities decrease and/or limit feed intake including, absorption and metabolism of nutrients imbalanced to meet a particular productive function (Dierenfeld *et al.*, 2002). Muscle fatigue /occur during seeking, ingesting, chewing and rumination of feed is another factor limiting feed intake as it tends to restrict rumination and the time taken to end the process.

2.3.1.2 Plant related factors

The acceptance or palatability of a feed has been related to both physical characteristics such as feed texture including hairs of hairiness and bulk density and the presence of anti-nutritional factors on the feeds, (Gutteridge and Shelton, 1998), including appetite depressant compounds such as volatile oils, nitrate, fluoroacetate, tannins, triterpenes, alkaloids, oxalates and soluble carbohydrates (Dierenfeld *et al.*, 2002; Norton, 2004). On the other hand, toxic substances such as cyanides are other plant related factors hindering feed intake by poisoning the animal, (Aganga and Tshwenyane, 2003). In addition, stage of growth, botanical fraction and feed species also affect feed intake. Variation in intake between forage and fodder species is mainly attributed to the concentration of secondary plant metabolites.

2.3.1.2.1 Stage of plant growth

Stage of growth is the most important factor influencing quality as it determines the nutritive value and decreases feeding value of the browse tree foliage species (Aganga and Tshwenyane, 2003). Foliage quality affects feed intake and the amount of concentrate needed to balance the diet.

2.3.1.2.2 Botanical fraction

Botanical fraction refers to proportion of leaves to stem or leaf to stem ratio (Crowder and Cheddah, 1982). Botanical fraction of plants affect feed intake. For instance, browses prefer feeding on nutritive components neglecting the less nutritive parts of a browse tree (Gutteridge and Shelton, 1998). Gutteridge and Shelton, (1998) further reported that, distribution of browse components in the tree canopy particularly leaves can influence selection of browsing animals. For instance, nutritive content of immature leaves of sward is fairly low but easily accessible,

whereas the nutritive content of mature leaves of sward is higher but much of these are in lower strata and inaccessible. Effect of feed botanical fraction on feed intake is related to digestibility with more leafy fractions being more digestible than woody fraction.

2.3.1.2.3 Effect of digestibility on feed intake

Intake of feeds may be limited by various factors, including low protein quality, low crude protein digestibility, low energy content, high salty content, plant secondary metabolites including volatile oils, nitrate, fluoroacetate, tannins, triterpenes, alkaloids, oxalates and soluble carbohydrates (Dierenfeld *et al.*, 2002 Norton, 2004). The higher the digestibility, the higher the intake due to feed passage (Ørskov and Ryle, 1990). However, high variability exist in terms of feed digestibility in different animals both domestic and wild ungulates. Feed digestibility and intake is proportional related to one another.

2.4 Digestibility of the browse tree foliages

Digestibility is defined as the proportion of a feed or nutrients in feeds apparently absorbed relative to the quantity consumed (McDonald *et al.*, 1995). Digestibility is a measure used to describe the nutritive value of forages and determine the quality of feeds in relation to its chemical constituents (Dynes and Schlink, 2002). Digestibility of plant material is related to the proportion of lignin in cell walls of the plant (Goering and Van Soest., 1970; Van Soest *et al.*, 1991). For instance a feed with low lignin content between 20-35% is highly digestible compared to those with high lignin content. Amount of feeds together with nutrients content absorbed by animals and digestibility depend on one another and they are proportional related to the quantity of feed consumed (McDonald *et al.*, 1995).

2.4.1 Factors effecting digestibility of the browse tree foliages

Digestibility of a feedstuff is affected by various factors including fiber content, stage of maturity and level of feeding.

2.4.1.1 Effect of fiber content on digestibility

Dietary fiber includes soluble fiber (neutral detergent fiber (NDF)), acid detergent fiber (ADF) which is characterized by low digestibility, although digestible with time; and acid detergent lignin (ADL) which is in digestible (Van Soest, 1996). When a feed contains high level of fibers, digestibility is lowered (Crowder and Cheddah 1982). Difference in digestibility potential of different forage species is mainly attributed to the extent of fiber and lignification as related the extent of release of feeds organic matter and thus affects both feeds organic matter and dry matter digestibility (Van Soest *et al.*, 1998).

2.4.1.2 Effect of Stage of growth on digestibility

Effect of stage of growth on digestibility of feeds includes reduction of the post-ruminal supply as a result of decreasing of the dry matter intake (Hoffman, 2006)) As plant maturity is accompanied by development of xylem tissue for water transport, accumulation of cellulose and other carbohydrates, mature edible components of plants are less digestible than young components (Upreti and Shrestha, 2006).

2.4.1.3 Effect of level of feeding on digestibility.

Generally an increase in the quantity of food eaten by an animal causes a faster rate of passage of digesta. The food is exposed to the action of digestive enzymes for a shorter period and its digestibility may be reduced. High reduction in digestibility is

expected for the slowly digested components of foods, that is the cell wall components. (McDonald *et al.*, 1995).

2.4.2 *In vitro* digestibility potentials of common browse species

In vitro organic matter digestibility potentials (IVOMD) of most browse tree foliage species are reported to range from 344-758 g/kg DM (Khanal and Subba, 2001; Rubanza *et al.*, 2005) as shown in Table 3. *In vitro* dry matter digestibility potential of browse species range from 300-847 g/kg DM (Shayo, 1997; Shayo and Udén, 1999; Mabibela *et al.*, 2006; Mtengeti *et al.*, 2006) as shown in Table 4.

Table 3: *In vitro* organic matter digestibility potential (IVOMD) of selected browse legume species (g/kg DM).

Species	IVOMD	Reference
<i>Acacia nilotica</i>	706	Rubanza <i>et al</i> (2005).
<i>Melia azedarach</i>	758	Khanal and Subba (2001).
<i>Ficus nemoralis</i>	645	Khanal and Subba (2001).
<i>Acacia angustissima</i>	344	Rubanza <i>et al</i> (2005).
<i>Acacia senegal</i>	607	Rubanza <i>et al</i> (2005).
<i>Acacia tortilis</i>	702	Rubanza <i>et al</i> (2005).

Table 4: Table 3: *In vitro* organic matter digestibility potential (IVOMD) of selected browse legume species (g/kg DM). *In vitro* dry matter digestibility potential of common browse species (g/kg DM)

Species	IVDMD	Reference
<i>Acacia nilotica</i>	502	Madibela <i>et al</i> (2006).
<i>Morus alba</i>	820	Shayo (1997).
<i>Lannea tomentosa</i>	300	Mtengeti <i>et al</i> (2006).
<i>Justicia</i> spp.	696	Mtengeti <i>et al</i> (2006).
<i>Acacia tortilis</i>	552	Shayo and Udén (1999).
<i>Acacia mangium</i>	518	Shayo and Udén (1999).
<i>Sesbania sesban</i>	847	Shayo and Uden (1999).

2.5 Feed evaluation techniques

Currently, different methods are available for feeds evaluation, though each of these methods depends on the nature of feed to be evaluated as well as the concerned animal. With regard to the current study, feed samples from eight different plants species were analyzed to assess nutritive values in terms of chemical composition to determine crude protein, ash content, and fiber content (NDF, ADF and ADL), minerals, as well as *in vitro* dry matter and organic matter digestibility.

2.5.1 Chemical composition

Based on proximate composition analysis feeds fall into moisture content, dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), nitrogen free extract (NFE), as detailed by McDonald *et al.* (1995) standard techniques. However, based on modified fiber analysis (Van Soest *et al.*, 1991) chemical composition of feeds is fractioned into DM, OM, CP, NDF, ADF and ADL. The CP analysis involves three steps, i.e. digestion, distillation and titration based on Kjeldahl techniques (AOAC 1990). Van Soest *et al.*, (1991) described technique for analysis of fiber fractions (NDF, ADF and ADL) of feeds such as complex carbohydrates by digesting foliage samples using neutral detergent solvents.

2.5.2 Digestibility

Digestibility of feedstuffs can be estimated through various methods including *in vitro*, *in situ*, *in sacco* and *in vivo* techniques (Oba and Allen, 2005). Feed evaluation techniques were developed to characterize digestibility of varieties of feedstuffs. These methods can be carried out through batch culture digestibility, enzyme digestibility, gas production and polyester bag technique. Furthermore, Oba and Allen, (2005) reported that, digestibility of the feeds can be measured in terms of

digestible energy (DE), digestible organic matter (DOM) and digestible dry matter (DDM). Digestibility of feeds can also be measured through total digestible nutrients (TDN) as an indirect way for estimation of feed digestibility (Dynes and Shrink, 2002). Apart from *in vitro* and *in vivo* evaluation techniques, researchers have also developed cheaper and faster techniques for measuring neutral detergent fiber digestibility (NDFD) using Near Infrared Reflectance Spectroscopy (NIRS) although the estimated values remain apparent digestibility rather than true digestibility values.

In the current study, *in vitro* digestibility technique was used as explained below.

2.5.3.1 *In vitro* digestibility

In vitro estimation of feed digestibility is important tool for ruminant nutritionists as it can be used to evaluate quality of feeds with the regard of their nutritive values. The process of feed evaluation involves incubation of the dried ground forages in flasks with rumen microbes for a given period of time (Oba and Allen, 2005). There are several techniques commonly used for determination of feeds digestibility, including two stages *in vitro* digestibility (Tilley and Terry, 1963) and *in vitro* gas production technique (Menke and Steingass, 1988).

2.5.3.2 Two stages *in vitro* digestibility

Based on the two stages *in vitro* digestibility techniques of Tilley and Terry (1963), digestibility of feedstuff is determined by incubation of feed samples in digestion tube containing a known volume of buffer rumen fluid and artificial saliva at ratio of 1:4 (rumen liquor: artificial saliva) at 39°C for 48 h. The second stage involves mixing of feeds with pepsin (an artificial enzyme) for 48 h; centrifuging; drying in

forced air oven at 105°C for 24 h; ignition in the Muffle furnace at 550°C for 24 h to determine organic matter digestibility (Tilley and Terry, 1963).

2.7 Research gap

The literature review has shown that several studies have been conducted on the utilization and nutritive value of browse tree fodder species at global, regional, national and local levels. However, there is limited information on nutritive value of browse tree fodder species in the specific study area and in particular the sites such as NARCO, Irkiushioibor, Kibaya, Sagara (Shayo *et al.*, 1996; Shayo,1997; Norton,1994; Abdulrazak *et al.*, 2000 ;Rubanza *et al.*, 2003., Rubanza *et al.*, 2005; Mokoboki *et al.*, 2011 and Azim *et al.*,2011).

2.8 Conceptual Framework

Productivity of ruminant livestock is determined by genetic, physiological, environmental factors (type and plane or level of nutrition, water, frequency of feeding and water intake); and their interactions. On the other hand, quality of feedstuffs consumed by the livestock contribute much to their livelihood and have serious impact to their daily performances including growth and reproduction. The influence of quality of tree foliage species browsed by livestock to their performance can be presented using different types of variables, *i.e.* independent, intermediate and dependent variables as shown in figure 1.

2.8.1 Independent variables

The quality and nutritional value of the tree foliages is a result of the complex interaction of climate change, land and water pollution, geographic location etc. These factors determine nutritional values of feeds and in turn determine the general

performance of the livestock for example, the animals feeding on low quality feeds tends to have poor performance and vice versa.

2.8.2 Intermediate variables

The poor quality of feeds may result into a series of negative impacts including insufficient supply of essential nutrients, abnormal body physiology, low life expectancy, low mating frequency and eventually low productivity. Meanwhile reverse of above explained trends results to the increasing productivity

2.8.3 Dependent variables

The low productivity of ruminant livestock is influenced by low growth rate caused by consuming poor quality feeds and vice versa. The following conceptual frame diagram highlights the general picture of the study by providing some tips of the key variables in relation to the problem.

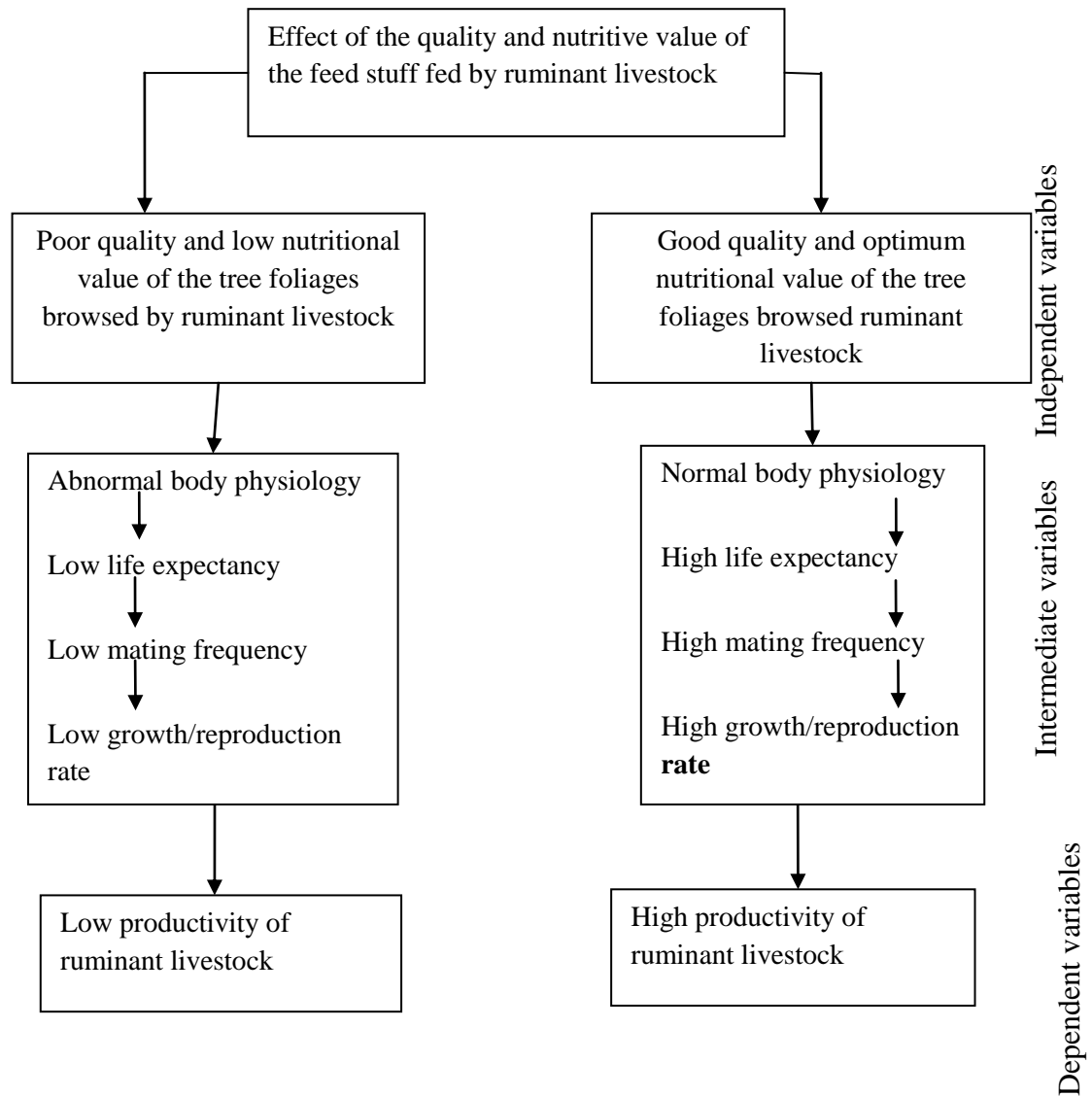


Figure 1: Conceptual framework.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study site

3.1.1 Location

The study was carried out in two districts, Kiteto district of Manyara region and Kongwa district of Dodoma region. Kiteto is located between $4^{\circ}31'$ - $6^{\circ}03'$ South; $35^{\circ}15'$ - $37^{\circ}25'$ East having an elevation of 1000-1500m and Kongwa situated at $5^{\circ}30'$ - $6^{\circ}0'$ South; $36^{\circ}15'$ - 36° East with an elevation of about 1000m above sea level.

The rangelands at which this study was carried out include Kongwa National Ranching Company NARCO, Sagara, Ugogoni for Kongwa district and Kibaya and Irkiushioibor for Kiteto district as shown in Figure 2. The sites were selected due to the fact that they are potentially good with enough number of livestock as well as easy accessibility of the areas.

3.1.2 Climate

The areas are characterized by long dry season and short rainy season with average annual rainfall of 450-550mm which varies widely in distribution and amount from year to year. The rain mostly fall between December and April, however there is usually spell in February. The average minimum temperature is 15.5°C and the average maximum temperature is 27.5°C .

3.1.2 Demography

The population of Kongwa district is estimated to be 309,973 while that of Kiteto is estimated to be 224,669 people (2012 census). Maasai and gogo pastoralists are the two major ethnic groups inhabiting the districts.

3.1.3 Vegetation

Generally the two districts are characterized by scattered trees and shrubs.

Cenchrus spp. and *Cynodon* spp are the dominant herbage species in the area, while *Aristida* spp. being a dominant grass species especially in degraded parts. The most dominant species is represented by *Acacia* species, *Combretum* species and *Brachystegia* species.

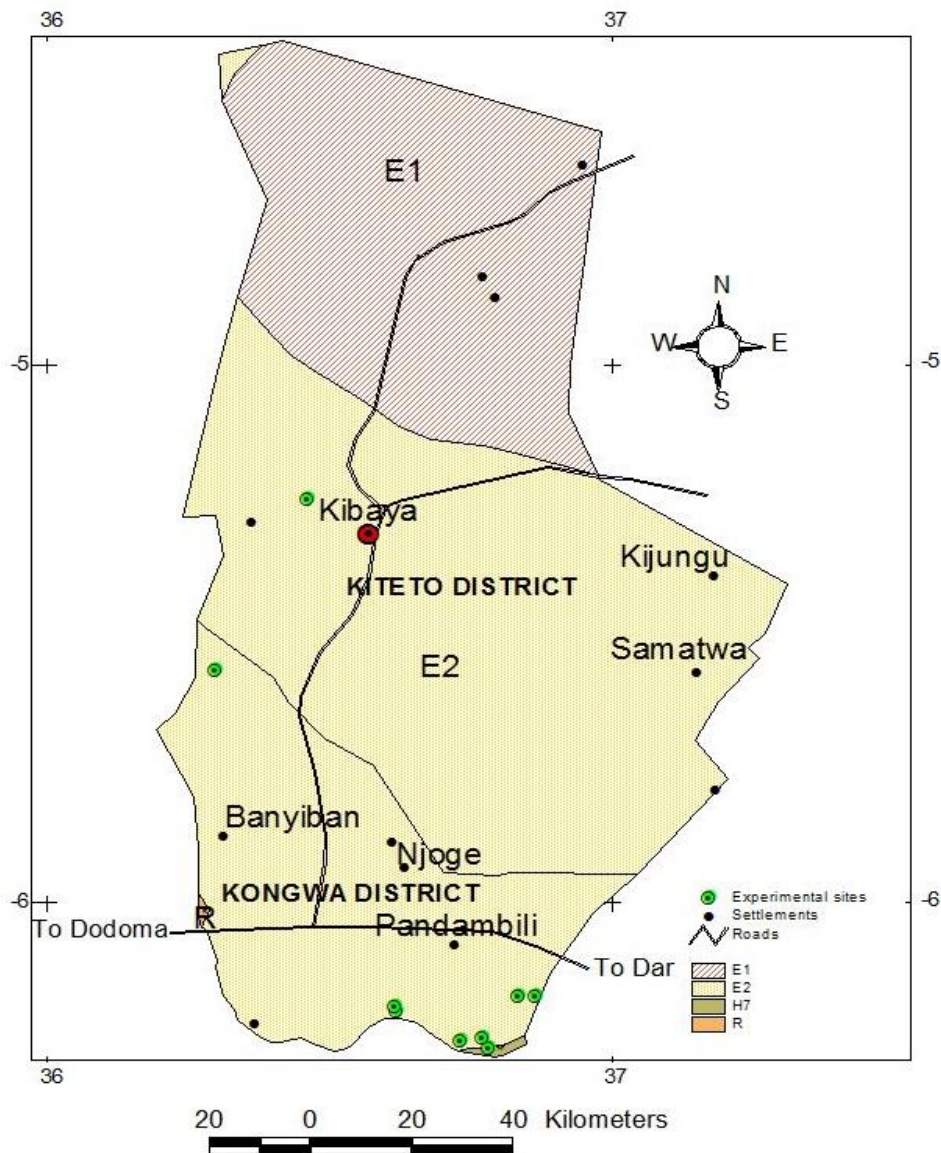


Figure 2: A map of Kongwa and Kiteto districts showing the study sites.

Source: Meliyo (2014). Consultancy Report submitted to ICRAF.

3.2 Experimental design

A completely randomized design was employed in this study based on an on-farm participatory feed resources assessment among pastoralists coupled with feed collection of promising priority fodder species' samples and later laboratory nutritive screening through assessment of potential chemical composition, mineral composition and *in vitro* digestibility. The leaves and twigs samples were randomly collected from about ten trees browse trees in the selected rangelands. After sample processing, laboratory analyses were done in duplicates/ triplicates so as to avoid extraneous errors.

3.2.1 Collection of samples

Browse tree foliages (leaves and twigs) were hand plucked from at least 10 promising browse tree species in each rangeland for both dry and wet seasons of the year 2013/2014. The harvested samples were collected into labeled bags for each species and site (Plate 1). The species include *Acacia tortilis*, *Acacia xanthophloea*, *Acacia senegal*, *Acacia mellifera*, *Boscia* spp, *Melia azedarach*, *Gliricidia sepium* and *Leucaena pallida*.

3.2.2 Processing of samples

Sample processing started immediately after field survey. Samples from the field were dried in the shade without exposing in the direct sun light to prevent photo oxidation. They were then sent to the laboratory for chemical analyses. The samples were dried in a draft oven set at 60°C for 48 h to constant weight then they were weighed, bulked per species, sub-sampled and ground to fine powder which passed through a 1mm sieve. The ground samples were thoroughly mixed weighed and

subjected to analysis of chemical composition (DM, Ash, CP, NDF, ADF, ADL, minerals) and *in vitro* dry matter and organic matter digestibility.

3.3 Laboratory analyses

Analyses of foliage samples for nutritive value were done in terms of chemical composition, including DM, Ash, CP, NDF, ADF, ADL, and minerals as described by AOAC (1990) as well as *in vitro* dry matter digestibility (IVDMD) *in vitro* organic matter digestibility (IVOMD) potential (Tilley and Terry,1963).

3.3.1 Dry matter content

Dry matter (DM) content was determined by placing known weight of ground sample in the air forced oven at 105°C overnight. DM weight was obtained by weighing and recording crucible containing sample from the oven as described by AOAC (1990).

3.3.2 Ash content

Ash content of foliage samples was determined by ashing crucible containing sample used to determine dry matter in a muffle furnace at 550°C for three hours or more. Then sample from muffle furnace was cooled in a desiccator, weighed and percentage of ash was determined as described by AOAC (1990).

3.3.3 Crude protein

The determination of total nitrogen (N) of foliage samples was done using Kjeldahl technique as seen in Plate 2(a), based on AOAC, (1990) standard procedures. Total nitrogen was determined through three different steps namely, digestion stage, distillation stage and titration stage. Samples were digested on heat using sulfuric acid (H₂SO₄), distilled using Boric acid (H₃BO₃) and sodium hydroxide (NaOH) and

finally were titrated against sulfuric acid. Content of CP was computed by multiplication of total nitrogen by conversion factor of 6.25 ($CP = N \times 6.25$).

3.3.4 Dietary fibers analysis

The determination of fiber was done through neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) as detailed by Van Soest *et al.*, (1991).

3.3.4.1 Neutral Detergent Fiber

The content of neutral detergent fiber (NDF) was determined using techniques described by Van Soest *et al.* (1991). About 0.5 g of sample was mixed with 45ml of neutral detergent solution in digestion flask and boiled at 60°C for 15 minutes to digest the sample (Plate 2b). The hot boiled sample from digestion flasks was filtered in the pre weighed empty crucible, washed with hot water and finally with acetone. Crucible containing cool filtered sample was placed in the forced air oven at 105°C overnight. Weight of crucible and sample was obtained by weighing crucible containing sample from pre put in desiccator and weight was recorded.

3.3.4.2 Acid detergent fiber

Acid detergent fiber (ADF) was analyzed using techniques described by Van Soest *et al.*, (1991). Foliage sample was mixed with acid detergent solution in digestion flask (Plate 2b) and boiled at 60°C, washed with hot water followed by acetone, dried at 105°C and for 24 h and weight of dry sample was recorded (Van Soest *et al.*, 1991).

3.3.4.2 Acid Detergent Lignin

Acid detergent lignin (ADL) was determined by using techniques described by Van Soest *et al.* (1991). Percentage of ADL content was determined by stirring ADF residues in porous crucible with sulfuric acid (H_2SO_4) for 4 h. The sample was dried in forced air oven at $105^\circ C$, then ignited in the muffle furnace at $550^\circ C$ for 24 h and weight of the ash was recorded.



Plate1: *Acacia xanthophloea* sample collected from Kibaya, Kiteto



a) Determination of CP by the Kjeldahl apparatus

b) Determination of NDF and ADF in digestion flasks

Plate 2: Determination of chemical composition

Source: Field data, 2013

3.3.4.3 Concentration of minerals.

The leaf samples were oven dried in a forced air oven at 105 °C to constant weight. Then they were ground to pass through a 1mm screen in a grinding mill for proximate analysis. The ground samples were weighed and ashed at 550 °C in a muffle furnace for 3 h then cooled and treated with 20 ml of 1:1 HCl acid for 24 h. The resulting mixture was filtered into a 100 ml volumetric flask and distilled water was added to 100 ml mark. Ca, Mg, S, Fe, Cu, Zn, Mn were determined using UNICAM 919 Atomic absorption spectrometer. (ASS). Phosphorus was analyzed by calorimetric method using PU 8620 UV/VIS/NIR Spectrophotometer in accordance to (A.O.A.C 1990).

3.5 *In vitro* digestibility potential

Determination of dry matter and organic matter digestibility potential of browse tree foliage feeds were done using *in vitro* digestibility techniques described by Tilley and Terry (1963). Digestibility of samples was determined by incubation of samples (Plate 4) into digestion tubes containing 50 ml buffer rumen fluid (Plate 3a and 3b) in a ratio of 1: 4 (rumen liquor: artificial saliva) at 39 °C for 48 h, then mixed with pepsin for 48 h, centrifuged, dried in forced air oven at 105 °C for 24 h, ignited in the Muffle furnace at 550°C for 24 h and weighed to explore weights of Dry matter and Organic matter.



a) Collecting rumen liquor from a fistulated cow



b) Filtered rumen liquor ready for use

Plate 3: Collecting and filtering rumen liquor from a fistulated cow.



Plate 4: Samples mixed with rumen liquor and artificial saliva being incubated

Source: Field data, 2014

3.7 Data processing and analysis

Data on normal chemical composition (DM, Ash, CP, NDF, ADF and ADL), digestibility potential (IVDMD and IVOMD) and concentration of macro and micro minerals of the browse tree foliages were analysed using Analysis of variance

(ANOVA) based on the General Linear Model (GLM) procedure (SAS/ Stat view 1999) based on the statistical model:

$$Y_{ij} = \mu + S_i + A_j (S_i * A_j) + \varepsilon$$

Whereby:

Y_{ij} = General response of the specific parameter under investigation.

μ = General mean peculiar to each observation

$S_i = i^{th}$ effect of species on the observed parameters

$A_j = j^{th}$ effect of season on the observed parameters

ε = Random error term for each estimate.

Means of the estimated parameters were compared by Duncan's Multiple range test.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND DISCUSSION OF THE FINDINGS

In this chapter, analysis and discussion of the results obtained in the current study are presented. The findings presented and discussion relies on the specific objectives underlying the study and comparisons are made from the previous works in similar area.

4.1 Results

4.1.1 Chemical composition

Results for chemical composition of the browse tree fodder species in terms of ash, crude protein, neutral detergent fiber and acid detergent fiber for both dry and wet seasons are presented as shown in Table 5.

Table 5: Chemical composition (g/kg DM) of leaves of selected browse tree fodder species indigenous to Kongwa and Kiteto districts

Species	ASH		CP		NDF		ADF		ADL	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
<i>A. mellifera</i>	73±7.9 ^{dc}	73±7.9 ^e	192±18.9 ^{ab}	283±18.9 ^a	570±10.6 ^a	450±10.6 ^c	325±82.1 ^{ab}	234±82.1 ^e	175±17.5 ^a	77±17.5 ^b
<i>A. senegal</i>	105±7.9 ^{ab}	127±7.9 ^c	215±18.9 ^a	215±18.9 ^e	506±10.6 ^b	545±10.6 ^b	319±82.1 ^{ab}	176±82.1 ^g	123±17.5 ^{abc}	54±17.5 ^c
<i>A. tortilis</i>	84±4.6 ^{bc}	69±7.9 ^e	187±10.9 ^{ab}	236±18.9 ^d	598±7.5 ^a	516±10.6 ^c	324±47.4 ^{ab}	187±82.1 ^f	140±10.1 ^{ab}	51±17.5 ^c
<i>A. xanthophloea</i>	55±7.9 ^d	75±7.9 ^e	130±18.9 ^b	161±18.9 ^b	342±10.6 ^d	398±10.6 ^f	212±82.1 ^b	277±82.1 ^d	38±17.5 ^d	94±17.5 ^a
<i>Boscia</i> spp.	98±7.9 ^{ab}	80±7.9 ^e	173±18.9 ^{ab}	258±18.9 ^b	609±10.6 ^a	644±10.6 ^a	384±82.1 ^{ab}	384±82.1 ^a	72±17.5 ^{cd}	56±17.5 ^c
<i>G. sepium</i>	116±4.6 ^a	237±7.9 ^a	230±10.9 ^a	181±18.9 ^g	419±10.6 ^c	512±10.6 ^c	343±47.4 ^{ab}	353±82.1 ^b	92±10.1 ^{bcd}	78±17.5 ^b
<i>L. pallida</i>	87±5.6 ^{bc}	162±7.9 ^b	212±18.9 ^a	189±18.9 ^f	477±10.6 ^b	481±10.6 ^d	184±58.0 ^b	313±82.1 ^c	44±12.4 ^d	83±17.5 ^b
<i>M. azedarach</i>	108±5.6 ^{ab}	116±7.9 ^d	184±13.4 ^{ab}	251±18.9 ^c	354±10.6 ^d	509±10.6 ^c	577±58.0 ^a	350±82.1 ^b	79±12.4 ^{cd}	81±17.5 ^b
Mean	90.8	117.4	190.4	221.8	484.4	503.1	333.5	284.3	95.4	71.8
SEM	6.5	7.9	16.2	18.9	10.2	10.6	67.4	82.1	14.4	17.5
Significant effect of :										
Species		***		**		***		*		*
Season		***		**		***		n.s		*
Species*Season		***		**		***		n.s		***

a, b, c, d, e, f, g, h Column means with different superscripts are significantly different ($P < 0.05$); CP is crude protein; NDF is neutral detergent fiber; ADF is acid detergent fiber; ADL is acid detergent lignin; DS is Dry season; WS is Wet season; SEM is Standard error of the mean. * ($P < 0.05$); ** ($P < 0.01$); *** ($P < 0.001$); n.s (The effect is not significant $P > 0.05$).

Source: Field work, 2014.

4.1.1. 1 Ash

Content of ash of the studied browse tree foliage species indigenous to Kongwa and Kiteto districts are presented in Table 5. In dry season there were variable ($P < 0.05$) levels of ash among the species which ranged from 73 g/kg DM (*Acacia mellifera*) to 116 g/kg DM (*Gliricidia sepium*). *Melia azedarach*, *Boscia* spp. and *Acacia senegal* had significantly similar ash content ($P > 0.05$) which was higher ($P < 0.05$) than other species except *Gliricidia sepium*. On the other hand, there was no difference ($P > 0.05$) in ash content between *Acacia tortilis* and *Leucaena pallida* which was higher ($P < 0.05$) than that of *Acacia mellifera* and *Acacia xanthophloea* (the lowest). In wet season, ash ranged ($P < 0.05$) from 69 g/kg DM (*Acacia tortilis*) to 237 g/kg DM (*Gliricidia sepium*). There was no difference ($P > 0.05$) in the content of ash between *Acacia mellifera*, *Acacia tortilis* and *Acacia xanthophloea* which was low ($P < 0.05$) compared to all other species.

4.1.1.2 Crude protein

Concentration of crude protein of the selected browse tree foliage species in Kongwa and Kiteto districts are similarly presented in Table 5. CP varied significantly between species ($P < 0.05$). In dry season CP varied ($P < 0.05$) from 130 g/kg DM (*Acacia xanthophloea*) to 230 g/kg DM (*Gliricidia sepium*). There was no significant difference ($P > 0.05$) in CP between *Acacia senegal*, *Gliricidia sepium* and *Leucaena pallida* which was the highest ($P < 0.05$) CP of all other species. Also *Acacia mellifera*, *Acacia tortilis*, *Boscia* spp. and *Melia azedarach* had significantly the same ($P > 0.05$) content of CP.

In wet season CP ranged ($P<0.05$) from 161 g/kg DM (*Acacia xanthophloea*) to 283 g/kg DM (*Acacia mellifera*). All species had significantly different ($P<0.05$) levels of CP, the highest being *Acacia mellifera* and *Acacia xanthophloea* was the lowest.

4.1.1.3 Neutral detergent fiber

In dry season neutral detergent fiber showed significant variation between species ($P<0.05$) which ranged from 342 g/kg DM (*Acacia xanthophloea*) to 609 g/kg DM (*Boscia* spp.). There was no difference ($P>0.05$) in NDF between *Acacia tortilis*, *Acacia mellifera* and *Boscia* spp. which was the highest ($P<0.05$) of all species. *Acacia senegal* and *Leucaena pallida* had similar ($P.>0.05$) content of CP which was higher ($P<0.05$) than that of *Acacia xanthophloea* and *Melia azedarach* (the lowest). In wet season NDF ranged from 398 g/kg DM (*Acacia xanthophloea*) to 644 g/kg DM (*Boscia* spp.). There was no difference ($P>0.05$) in NDF between *Acacia tortilis*, *Gliricidia sepium* and *Melia azedarach* which was higher ($P<0.05$) than *Leucaena pallida*, *Acacia mellifera* and *Acacia xanthophloea*. *Boscia* spp. had the highest ($P<0.05$) NDF (644 g/kg DM) whereas *Acacia xanthophloea* had the lowest (398 g/kg DM).

4.1.1.4 Acid detergent fiber

In dry season, acid detergent fiber varied significantly among the species ($P<0.05$) which ranged from 184 g/kg DM (*Leucaena pallida*) to 577 g/kg DM (*Melia azedarach*). There was no difference ($P>0.05$) in ADF between the browse species except *Acacia xanthophloea*, *Leucaena pallida* and *Melia azedarach*. *Leucaena pallida* and *Acacia xanthophloea* had significantly the same ADF (184 and 212 g/kg DM) respectively which was the lowest of all species in the current study. *Melia azedarach* (577 g/kg DM) had the highest ADF. In wet season, ADF ranged from

(176-384) g/kg DM for *Acacia senegal* and *Boscia* spp. respectively. There was no difference in ADF between *Gliricidia sepium* and *Melia azedarach* which was higher than the rest of species except *Boscia* spp. The lowest ($P < 0.05$) ADF was observed in *Acacia senegal* (176 g/kg DM) compared to the highest ADF in *Boscia* spp. (384 g/kg DM).

4.1.1.5 Acid detergent lignin

Results for acid detergent lignin of the browse species under study are also presented in Table 5. During dry season, acid detergent lignin significantly varied between species ($P < 0.05$) which ranged ($P < 0.05$) from 38 g/kg DM (*Acacia xanthophloea*) to 175 g/kg DM (*Acacia mellifera*). *Melia azedarach* and *Boscia* spp. had significantly the same level of ADL which was different from other species. There was no difference ($P > 0.05$) in ADL between *Leucaena pallida* and *Acacia xanthophloea* which was the lowest ($P < 0.05$) of all. During wet season, ADL varied ($P < 0.05$) from 51 g/kg DM (*Acacia tortilis*) to 94 g/kg DM (*Acacia xanthophloea*). There was no difference ($P > 0.05$) in ADL between *Acacia mellifera*, *Gliricidia sepium*, *Leucaena pallida* and *Melia azedarach* which was lower ($P < 0.05$) than *Acacia xanthophloea* (the highest). The lowest ($P < 0.05$) ADL was found in *Acacia senegal*, *Acacia tortilis* and *Boscia* spp which had significantly similar ($P > 0.05$) ADL (51-56) g/kg DM.

4.1.2 *In vitro* digestibility

Results for *in vitro* digestibility of leaves of common browse species indigenous to Kongwa and Kiteto districts for dry and wet seasons are presented in Table 6.

Table 6: In vitro digestibility potential (g/kg DM) of the selected browse foliage species indigenous to Kongwa and Kiteto districts for dry and wet seasons

Species	IVOMD		IVDMD	
	Dry season	Wet season	Dry season	Wet season
<i>Acacia mellifera</i>	370±16.0 ^{cd}	485±16.0 ^c	377±4.5 ^d	476±4.5 ^c
<i>Acacia senegal</i>	411±16.0 ^c	516±16.0 ^{bc}	422±4.5 ^c	525±4.5 ^b
<i>Acacia tortilis</i>	357±16.0 ^{de}	509±16.0 ^{bc}	356±4.5 ^e	531±4.5 ^b
<i>Acacia xanthophloea</i>	503±16.0 ^b	394±16.0 ^d	490±4.5 ^b	383±4.5 ^e
<i>Boscia</i> spp	320±16.0 ^e	386±16.0 ^d	325±4.5 ^f	399±4.5 ^d
<i>Gliricidia sepium</i>	671±16.0 ^a	608±16.0 ^a	658±4.5 ^a	560±4.5 ^a
<i>Leucaena pallida</i>	406±16.0 ^c	419±16.0 ^d	415±4.5 ^c	402±4.5 ^d
<i>Melia azedarach</i>	411±16.0 ^c	546±16.0 ^b	411±4.5 ^c	537±4.5 ^b
Mean	431.1	495.4	431.8	476.6
SEM	16.0	16.0	4.5	4.5
Species	***		***	
Season	***		***	
Species*Season	***		***	

^{a,b,c,d,e,f} Column means with different superscripts differ significantly ($P<0.05$); IVOMD is *In vitro* organic matter digestibility potential; IVDMD is *In vitro* dry matter digestibility potential; SEM is standard error of the mean; *** ($P<0.001$).

Source: Field data, 2014.

4.1.12.1 *In vitro* organic matter digestibility

In vitro organic matter digestibility potential (IVOMD) of leaves of the selected browse tree foliage species native to Kongwa and Kiteto districts are presented in Table 6.

IVOMD potential varied significantly between species ($P < 0.05$). In dry season, IVOMD ranged ($P < 0.05$) from 320 g/kg DM (*Boscia* spp.) to 671 g/kg DM (*Gliricidia sepium*). There was significant difference ($P < 0.05$) in IVOMD among the species ($P < 0.05$). *Leucaena pallida* and *Melia azedarach* had significantly the same ($P > 0.05$) value of IVOMD which was different ($P < 0.05$) from the rest of the species. In wet season, IVOMD ranged ($P < 0.05$) from 386 g/kg DM to 608 g/kg DM, *Gliricidia sepium* being the highest and *Boscia* spp. was the lowest ($P < 0.05$). *Acacia senegal* and *Acacia tortilis* had significantly the same ($P > 0.05$) value of IVOMD which was higher than those of all other species except *Gliricidia sepium* ($P < 0.05$). There was no significant difference ($P > 0.05$) in IVOMD between *Acacia xanthophloea*, *Boscia* spp. and *Leucaena pallida* in the wet season.

4.1.12.2 *In vitro* dry matter digestibility

In vitro dry matter digestibility (IVDMD) potential of the selected browse species leaves in Kongwa and Kiteto are similarly presented in Table 6. IVDMD potential varied significantly between species ($P < 0.05$). In dry season, IVDMD ranged ($P < 0.05$) from (325-658) g/kg DM for *Boscia* spp. and *Gliricidia sepium* respectively. The species had significantly different values of IVDMD ($P < 0.05$) except *Leucaena pallida* and *Melia azedarach* which had statistically the same IVDMD potential ($P > 0.05$). In wet season IVDMD varied ($P < 0.05$) between 383 g/kg DM (*Acacia xanthophloea*) and 560 g/kg DM (*Gliricidia sepium*). There was

no significant difference in IVDMD ($P>0.05$) between *Acacia tortilis*, *Acacia senegal* and *Melia azedarach* which was higher ($P<0.05$) than the rest of the species with the exception of *Gliricidia sepium*. *Boscia* spp and *Leucaena pallida* had significantly similar ($P>0.05$) IVDMD potential which was lower ($P<0.05$) than that of *Acacia xanthophloea*.

Table 7: Concentration of macro minerals (g/kg DM) of the selected browse species in Kongwa and Kiteto districts.

Species	Ca		Mg		S		P	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
<i>A. mellifera</i>	2.3±0.02 ^e	3.1±0.02 ^f	2.0±0.01 ^c	3.1±0.01 ^e	1.5±0.01 ^d	1.5±0.01 ^g	1.9±0.02 ^{ef}	2.3±0.01 ^e
<i>A. senegal</i>	5.5±0.02 ^c	10.9±0.02 ^b	1.4±0.01 ^{cd}	2.3±0.01 ^g	1.8±0.01 ^c	2.2±0.01 ^e	1.7±0.02 ^f	1.8±0.01 ^g
<i>A. tortilis</i>	6.0±0.02 ^c	7.2±0.02 ^e	2.2±0.01 ^c	2.8±0.01 ^f	2.8±0.01 ^a	2.8±0.01 ^b	2.8±0.02 ^{cd}	3.0±0.01 ^c
<i>A.xanthophloea</i>	8.9±0.02 ^b	7.9±0.02 ^d	3.7±0.01 ^b	4.9±0.01 ^b	1.8±0.01 ^c	2.8±0.01 ^b	2.3±0.02 ^{de}	2.8±0.01 ^d
<i>Boscia spp</i>	1.8±0.024	2.2±0.02 ^h	6.4±0.01 ^a	6.6±0.01 ^a	2.6±0.01 ^b	2.4±0.01 ^c	3.8±0.02 ^b	4.1±0.01 ^b
<i>G. sepium</i>	9.5±0.02 ^a	8.9±0.02 ^c	4.6±0.01 ^b	4.4±0.01 ^c	3.1±0.01 ^a	2.9±0.01 ^a	3.0±0.02 ^c	2.8±0.01 ^d
<i>L. pallida</i>	3.4±0.02 ^d	2.9±0.02 ^g	5.4±0.01 ^b	4.1±0.01 ^d	1.9±0.01 ^{bc}	2.1±0.01 ^f	2.3±0.02 ^{de}	2.2±0.01 ^f
<i>M. azedarach</i>	8.7±0.02 ^b	12.6±0.02 ^a	2.0±0.01 ^d	1.9±0.01 ^h	1.8±0.01 ^c	2.3±0.01 ^d	6.6±0.02 ^a	7.1±0.01 ^a
Mean	5.8	7.0	3.5	3.8	2.2	2.0	3.1	3.3
SEM	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01

Significant effect of:

Species	****	***	***	***
Season	***	***	***	***
Species*season	***	***	***	***

a, b, c, d, e, f, g, h Column means with different superscripts are significantly different ($P<0.05$); Mg=Magnesium; Ca= Calcium; S = Sulfur; P=Phosphorus; ***

($P<0.001$), SEM is Standard error of the mean.

Source: Field work, 2014

Table 8: Concentration of micro minerals (mg/kg DM) of the selected browse species in Kongwa and Kiteto districts.

Species	Fe		Cu		Zn		Mn	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
<i>A. mellifera</i>	229±0.6 ^d	235±0.6 ^d	32.5±0.06 ^c	40.1±0.06 ^b	16.5±0.06 ^g	23.4±0.06 ^d	35.4±0.06 ^d	43.2±0.96 ^c
<i>A. senegal</i>	243±0.6 ^c	267±0.6 ^a	4.2±0.06 ^h	4.8±0.06 ^g	19.2±0.06 ^f	22.1±0.06 ^e	26.8±0.06 ^g	27.6±0.96 ^f
<i>A. tortilis</i>	171±0.6 ^g	201±0.6 ^g	53±0.06 ^a	39.1±0.06 ^c	46.0±0.06 ^a	12.2±0.06 ^h	13.1±0.06 ^h	32.6±0.96 ^e
<i>A.xanthophloea</i>	198±0.6 ^f	218±0.6 ^f	6.1±0.06 ^f	9.2±0.06 ^d	31.2±0.06 ^b	34.2±0.06 ^a	74.2±0.06 ^b	63.2±0.96 ^b
<i>Boscia spp</i>	211±0.6 ^e	217±0.6 ^f	9.8±0.06 ^e	7.4±0.06 ^f	15.2±0.06 ^h	21.2±0.06 ^f	56.4±0.06 ^c	36.8±0.96 ^d
<i>G. sepium</i>	300±0.6 ^a	259±0.6 ^b	5.0±0.06 ^g	4.2±0.06 ^h	21.0±0.06 ^e	19.0±0.06 ^g	80.9±0.06 ^a	77.0±0.96 ^a
<i>L. pallida</i>	251±0.6 ^b	241±0.6 ^c	12.5±0.06 ^d	8.9±0.06 ^c	26.0±0.06 ^d	29.0±0.06 ^b	31.5±0.06 ^f	33.5±0.96 ^e
<i>M. azedarach</i>	155±0.6 ^h	232±0.6 ^e	35.8±0.06 ^b	42.2±0.06 ^a	27.3±0.06 ^c	24.1±0.06 ^c	33.2±0.06 ^e	43.6±0.96 ^c
Mean	219.8	233.8	19.9	19.5	25.3	23.2	43.9	44.7
SEM	0.6	0.6	0.06	0.06	0.06	0.06	0.06	0.96
Significant effect of:								
species	***		***		***		***	
season	***		***		***		***	
Species*season	***		***		***		***	

a, b, c, d, e, f, g, h Means with similar superscripts along the same column do not differ significantly (P>0.05); *** (P<0.001); Mn= Manganese; Fe= Iron; Cu= Copper; Zn= Zinc.

4.1.3 Concentration of minerals

Results for concentration of both macro and micro minerals of the studied browse tree species are presented.

4.1.3.1 Macro minerals

Concentrations of macro minerals of the browse species are presented in Table 7. During dry season the species had variable contents of Calcium ($P<0.05$) that ranged from 2.3 g/kg DM (*Acacia mellifera*) to 9.5 g/kg DM (*Gliricidia sepium*). *Acacia senegal* and *Acacia tortilis* had significantly the same ($P>0.05$) concentration of calcium which was higher ($P<0.05$) than the rest of the species except *Melia azedarach*, *Acacia xanthophloea* and *Gliricidia sepium*. In wet season there was significant difference ($P<0.05$) in concentrations of Calcium among the species which ranged from 2.2 (*Boscia* spp) to 12.6 g/kg DM (*Melia azedarach*).

During dry season, the levels of Phosphorus varied ($P<0.05$) among the browse species from 1.7 g/kg DM (*Acacia senegal*) to 6.6 g/kg DM (*Melia azedarach*). *Acacia xanthophloea* and *Leucaena pallida* had similar ($P>0.05$) concentration of Phosphorus which was higher ($P<0.05$) than that of *Acacia mellifera* and *Acacia senegal* and differed significantly from the rest of the species ($P<0.05$). In wet season Phosphorus concentrations among the species were variable ($P<0.05$), which ranged from 1.8 g/kg DM (*Acacia senegal*) to 7.1 g/kg DM (*Melia azedarach*). All the species had significantly different contents of Phosphorus ($P<0.05$).

In dry season the species had variable contents of Magnesium ($P<0.05$) that ranged from 1.4 g/kg DM (*Acacia senegal*) to 6.4 g/kg DM (*Boscia* spp.). In wet season there was variation in Magnesium concentrations among the species ($P<0.05$) which ranged from 1.9 g/kg DM (*Melia azedarach*) to 6.6 g/kg DM (*Boscia* spp.). The

concentrations of sulfur in dry season varied significantly ($P<0.05$) among the browse species leaves from 1.5 g/kg DM (*Acacia mellifera*) to 3.1 g/kg DM (*Gliricidia sepium*). *Acacia tortilis* and *Gliricidia sepium* had the highest ($P<0.05$) concentration of S which was different ($P<0.05$) from all other species. *Acacia senegal*, *Acacia xanthophloea* and *Melia azedarach* had significantly the same ($P>0.05$) level of Sulfur which was lower ($P<0.05$) than the rest of the species except *Acacia mellifera*. In wet season concentrations of Sulfur varied significantly between species ($P<0.05$) which ranged from 1.5 g/kg DM (*Acacia mellifera*) to 2.9 g/kg DM (*Gliricidia sepium*). *Acacia tortilis* and *Acacia xanthophloea* had significantly similar ($P>0.05$) concentration of S which was higher ($P<0.05$) than all other species except *Gliricidia sepium*.

4.1.3.2 Micro minerals

Concentrations of micro minerals of common browse tree fodder species in Kongwa and Kiteto districts are presented in Table 8. In dry season concentration of iron varied ($P<0.05$) among the species from 155 mg/kg DM (*Melia azedarach*) to 300 mg/kg DM (*Gliricidia sepium*). In wet season concentration of Iron ranged from 201 mg/kg DM to 267 mg/kg DM for *Acacia tortilis* and *Acacia senegal* respectively ($P<0.05$). *Acacia xanthophloea* and *Boscia* spp. had significantly the same ($P>0.05$) concentration of iron which differed significantly ($P<0.05$) from the rest of the species. Levels of copper (Cu) varied significantly ($P<0.05$) between the browse species which ranged from 4.2 mg/kg DM to 53 mg/kg DM for *Acacia senegal* and *Acacia tortilis* respectively during the dry season. In wet season the species had significantly ($P<0.05$) different concentrations of Copper which varied from 4.2 mg/kg DM (*G. sepium*) to 42.4 mg/kg DM (*Melia azedarach*). The content of Zinc was variably different among the species ($P<0.05$). In dry season concentration of

Zn ranged ($P<0.05$) from 15.2 mg/kg DM (*Boscia* spp) to 46 mg/kg DM (*Acacia tortilis*) where as in wet season the range was 12.2 mg/kg DM (*Acacia tortilis*) to 34.2 mg/kg DM (*Acacia xanthophloea*).

Concentrations of Manganese among the species varied significantly ($P<0.05$) from 13.1 mg/kg DM (*Acacia tortilis*) to 80.9 mg/kg DM (*Gliricidia sepium*) in dry season. In wet season concentrations of Manganese ranged from 27.6 mg/kg DM (*Acacia senegal*) to 77 mg/kg DM (*Gliricidia sepium*) which differed significantly between all species in the current study ($P<0.05$).

4.2 Discussion of findings

4.2.1 Chemical composition

Ash contents of species in the current study were relatively high (55-116) g/kg DM which suggests that the browse species could have high mineral concentrations therefore potential as feed supplements to ruminant livestock fed on low quality roughages. The ash levels noted in the browse species in the current study were consistent with that ranging from (135-143) g/kg DM (Topps, 1992; Shayo, 1997; Abdulrazak *et al.*, 2000) The ash contents in the current study were comparable to ash contents reported elsewhere (Azim *et al.*, 2011) for browse species which ranged from 53-139 g/kg DM for *Melia azedarach* and *Grewia optiva* respectively. However ash contents in this study were lower than that reported by Rubanza *et al* (2006) which ranged from 88 g/kg DM (*Boscia* spp.) to *Salvadora persica* (271 g/kg DM).

In both seasons the browse species had CP content above 80 g/kg DM which is adequate for ruminant diets (Annison and Bryden, 1998). The observed high CP values in the current study were comparable to those reported by Shayo (1997);

Abdulrazak *et al* (2000); Rubanza *et al* (2003); Rubanza *et al* (2006); Mtui *et al* (2009) and Mokoboki *et al* (2011) for browse species which ranged from 111 g/kg DM to 300 g/kg DM. The high CP (230 g/kg DM) of *Gliricidia sepium* in the current study was higher than that reported by Mtui *et al* (2009) for the same species in semi-arid areas of Morogoro which had CP of 212 g/kg DM. The CP results were within the range of 120-300 g/kg DM reported for indigenous browse species in semi-arid Central Tanzania by Ollson *et al* (1989) and Mtengeti *et al* (2006). The high CP in all the studied browse species implies that these species have a potential for use as protein supplement to ruminants fed on low quality feeds such as hay, stovers and crop residues.

NDF in the current study (342-609) g/kg DM was within the range of (154-619) g/kg reported by Shayo (1997); Rubanza *et al* (2006); Mtengeti *et al* (2006) and Mtui *et al* (2009). Results for ADF (176-384) g/kg DM were consistent to those reported by Rubanza *et al* (2003) and Mokoboki *et al* (2011). ADL contents for browse species in the current study (38-175) g/kg DM were comparable to the results of Mtui *et al* (2009) which ranged from (33-110) g/kg DM. The content of ADL in the current study was lower than that reported by Ollson and Welin (1989) which varied from (110-210) g/kg DM. The low ADL level (38 g/kg DM) in *Acacia xanthophloea* (dry season) was consistent to that of *Morus alba* (33 g/kg DM) reported by Mtui *et al* (2009). Abdulrazak *et al* (2000) also reported low level of ADL (42 g/kg DM) comparable to that of *Acacia xanthophloea* in the current study. The relatively low contents of fibers in the current study especially the ADL could reflect that the browse species leaves are well digestible as suggested by Van Soest *et al* (1991).

The observed differences on crude protein, ash content and fiber fractions (NDF, ADF and ADL) between species in dry and wet seasons is probably due to the effect of genotype on nutrient uptake, properties of soil to supply nutrients to plant, stage of growth, plant maturity, (Upreti and Shrestha, 2006), as well as the proportion of different browsed components in the harvested samples.

4.2.2 *In vitro* digestibility

Results from this study show that most of the species had high levels of *in vitro* organic matter digestibility as well as *in vitro* dry matter digestibility potentials. The observed high IVOMD in the current study (320-671) g/kg DM were consistent to the findings of other studies. Contents of IVOMD potentials were within the range of the findings of Rubanza *et al* (2005) for *Acacia* species and Khanal and Subba (2001) for other browse species which ranged from 344-810 g/kg DM. Similarly the results in the current study revealed high IVDMD among the browse species (325-658) g/kg DM that were comparable to the findings reported elsewhere (300-847) g/kg DM (Shayo, 1997; Shayo and Udén, 1999; Madibela *et al.*, 2006; Mtengeti *et al.*, 2006). There were noted variations in terms of IVOMD and IVDMD potential. The existing variations among species in the current study could be partly associated to the influence of accumulation of fiber fraction as a result of stage of growth, plant maturity and proportion of tree components taken for analysis of chemical composition. The data reported in this study indicate that the leaves from a range of browse trees in Kongwa and Kiteto districts have a good potential to supply highly digestible feeds for ruminants.

4.2.3 Macro minerals

In the current study, the species had detectable levels of Ca in both dry and wet seasons which ranged from 2.3-9.5 g/kg DM and 2.2-12.6 g/kg DM respectively. Ca levels in this study were within the range of 8.6-10.2 g/kg DM reported for most tropical legumes (Minson, 1990) and in range with Abdulrazak *et al* (2000) (3.2-14.2 g/kg DM). The Ca concentrations in the species also were within the levels recommended for beef cattle (2 g/kg DM) and sheep (2.1-4.2 g/kg DM) (NRC, 1984). However Ca concentrations in the current study were slightly lower than those reported by Rubanza (2005); Rubanza *et al* (2006) and Mtui *et al* (2008) which ranged from 6.6-35.6 g/kg DM.

Phosphorus levels in the current study (1.7-6.6 g/kg DM) were higher than that reported elsewhere for *Acacia* species (0.7-1.6 g/kg DM) (Abdulrazak *et al.*, 2000). The P levels were within the range of (1.0- 5.0 g/kg DM) noted by Rubanza *et al* (2006) Mtengeti *et al* (2006) and Mtui *et al* (2008). The P contents were within the minimum requirements for beef cattle and sheep (3.1-4.0 g/kg DM) and (1.6-3.2 g/kg DM) respectively (NRC, 1981).

The species had high levels of magnesium (1.4-6.6 g/kg DM) which were consistent to the minimum requirements (g/kg DM) in the diets of beef cattle (0.5-7.0) and higher than that for sheep diets (0.4-0.8 g/kg DM) (NRC,1984). The contents of Mg in the browse species were comparable to that of legume species (1.3-6.6 g/kg DM) studied elsewhere. (Abdulrazak *et al.*, 2000; Rubanza *et al.*, 2006; Mtengeti *et al.*, 2006 and Mtui *et al.*, 2008).

Concentrations of sulfur among the browse species (1.5-3.1 g/kg DM) were within the minimum requirements of diets for sheep (1.4- 2.5) g/kg DM and goats (1.6-3.2)

g/kg DM (NRC, 1978). The S contents observed in the species in the current study were consistent to those reported by Abdulrazak *et al* 2000 for *Acacia* spp.

4.2.4 Micro minerals

The browse species in the current study had high levels of Cu (4.2-53 mg/kg DM) for *Acacia senegal* and *Acacia tortilis* respectively. Most of the species had Cu concentrations (4.2-35.8) mg/kg DM comparable to most tropical legumes (15-35 mg/kg DM) (Minson, 1990). *Acacia senegal*, *Acacia xanthophloea*, *Boscia* spp. and *G. sepium* had Cu concentrations (4.2-9.8 mg/kg DM) which were within the range of (5.1-9.9 mg/kg DM) reported by Rubanza *et al* (2006) and Kakengi *et al* (2007) as well as the minimum requirements of beef cattle diets (NRC,1981). However, the range of Cu concentrations in browse species in the current study were higher than the minimum requirements of beef cattle (4-10 mg/kg DM), sheep and goats diets (0.1 mg/kg DM) (NRC, 1981). *Acacia tortilis* had exceptionally higher Cu content (53 mg/kg DM) than the rest of the species which was comparable to high concentration of Cu for *Acacia senegal* (54 mg/kg DM) noted by Abdulrazak *et al* (2000).

Concentrations of Fe in the browse species were high (155-300 mg/kg DM) which were within the range of (146.2-432) mg/kg DM reported for tropical browse species (Rubanza, 2005). However the species had slightly lower Fe contents than most forages and legumes (100-700) mg/kg DM suggested by McDowell (1992) and lower than the range of (126-851 mg/kg DM) for browse species (Abdulrazak *et al.*, 2000 and Rubanza *et al.*, 2006). The concentrations of Fe in all the browse species were higher than the normal requirements of ruminants (McDowell, 1992) (30-60

mg/kg DM), the minimum requirements of beef cattle (50-100 mg/kg DM) and sheep (NRC, 1989).

The species had Mn contents which ranged ($P < 0.05$) from 13.1 g/kg DM (*A. tortilis*) to 80.9 g/kg DM (*G. sepium*). These values were slightly higher than the minimum requirements of the diets of beef cattle 20-50 mg/kg DM), sheep (20-40 mg/kg DM) and goats (> 5 mg/kg DM) (NRC, 1978). The Mn concentrations in this study were lower than those reported by Rubanza, 2006 (44.6-306 mg/kg DM) and were within the range of 9.4-67.8 mg/kg DM reported by Abdulrazak *et al* (2000) and Kakengi *et al* (2007).

Browse species in the current study (15.2-46 mg/kg DM) had lower levels of Zn than mean concentration of most forages (36-47 mg/kg DM) except for *Acacia tortilis* (Minson, 1990). Most of the species could meet the minimum requirements for ruminant diets (20-40 mg/kg DM) (NRC, 1981). The contents of Zn were in range with the values (10.2-34.7) mg/kg DM reported by Abdulrazak *et al* (2000); Rubanza *et al* (2006) and Kakengi *et al* (2007).

Browses are generally rich in mineral contents which vary among the species possibly due to genotypic differences among the species, variability in mineral uptake and retention efficiency in plants, stage of foliage maturity and proportion of leaf samples (Minson, 1990). Variations in the concentrations of minerals among the browse species could also be accounted for by differences in the nature of soils, soil fertility and mineral status of soil among rangeland locations.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND AREAS FOR FURTHER STUDY

5.1 Summary of the main findings

The main findings underlying the current study include:

- Browse species in the current study had moderate to high contents of ash which varied significantly between species ($P<0.05$) which ranged from 73 g/kg DM (*A. mellifera*) to 116 g/kg DM (*G. sepium*) in dry season and 69 g/kg DM to 273 g/kg DM (*G. sepium*) in wet season.
- All the browse species in the current study had high CP which varied ($P<0.05$) among the species from *Acacia xanthophloea* (130 g/kg DM) to *G. sepium* (230 g/kg DM) in dry season and 161 g/kg DM (*Acacia xanthophloea*) to 283 g/kg DM (*Acacia mellifera*) in wet season. The species had CP values higher than 80 g/kg DM which can provide the minimum ammonia levels required by ruminants (Annison and Bryden, 1998).
- The species had moderate to low ($P<0.05$) contents of fibers. Neutral detergent fiber was lowest ($P<0.05$) in *A. xanthophloea* (342 g/kg DM) and highest ($P<0.05$) in *Boscia* spp (644 g/kg DM) for both seasons. Acid detergent fiber varied ($P<0.05$) among the species from 184 g/kg DM (*Leucaena pallida*) to *Melia azedarach* (577 g/kg DM). Acid detergent lignin was highest ($P<0.05$) in *Acacia mellifera* (175 g/kg DM) and lowest in *Acacia xanthophloea* (38 g/kg DM).
- Low contents of fibers in the browse species are associated with high digestibility potential.

- The browse species had high ($P<0.05$) contents of macro minerals. Ca ranged from 2.2 g/kg DM (*Boscia* spp) to *M. azedarach* (12.6 g/kg DM. P concentrations among the species were variable ($P<0.05$), which ranged from 1.8 g/kg DM (*Acacia senegal*) to 7.1 g/kg DM (*Melia azedarach*). The species had variable contents of magnesium ($P<0.05$) that ranged from 1.4 g/kg DM (*Acacia senegal*) to 6.4 g/kg DM (*Boscia* spp.). The concentrations of sulfur varied significantly ($P<0.05$) among the browse species leaves from 1.5 g/kg DM (*Acacia mellifera*) to 3.1 g/kg DM (*Gliricidia sepium*).
- Concentrations of micro minerals among the species were moderate to high ($P<0.05$). Concentrations of Cu (4.2-53 g/kg DM) were high compared to the values recommended for Cu in the diets of ruminant animals for their normal physiological functions (7-11 mg/kg DM). The Fe concentrations (155-300 mg/kg DM) were higher than the recommended dietary requirements for ruminants (30-60 mg/kg DM). The contents of Mn were slightly higher than the minimum requirements of the diets of beef cattle 20-50 mg/kg DM), sheep (20-40 mg/kg DM) and goats (>5 mg/kg DM). Browse species in the current study (15.2-46 mg/kg DM) had lower levels of Zn than most forages (36-47 mg/kg DM) but could meet the minimum requirements for ruminant diets (20-40 mg/kg DM).
- There were variation in *in vitro* digestibility potential among the species ($P<0.05$). *Gliricidia sepium* had both the highest ($P<0.05$) IVOMD (671 g/kg DM) and IVDMD (658 g/kg DM) among the species. *Boscia* spp. on the other hand had the lowest content of IVOMD (320 g/kg DM) and IVDMD (325 g/kg DM).

5.2 Conclusion

These results indicate that there are a number of promising species indigenous to Kongwa and Kiteto districts flora. As it has been observed all the studied browse species had high crude protein concentrations greater than 80 g/kg DM which is considered adequate as it can provide the minimum nitrogen levels required by ruminants. Furthermore, the species are also rich in concentrations of both macro and micro minerals necessary for normal physiological functioning of ruminant animals. The browse species had high *in vitro* organic matter digestibility as well as *in vitro* dry matter digestibility potentials suggesting that they can readily be utilized by ruminant livestock and improve productivity in the area. Therefore, all the eight browse species in the current study can be used as protein supplements to ruminant livestock fed on low quality feeds such as hay, stovers and crop residues.

5.3 Recommendations

- Following the current results it is recommended that those species which appear to be candidate species out of the rest by leading in the crude protein, mineral contents and potential digestibility should be noted.
- Species such as *Gliricidia sepium* and *Melia azedarach* which are exotic, but yet they perform well in these semi- arid areas can be integrated into farming systems, planted nearby the farmers 'homes for shade as well as feeding livestock.
- Also, *Acacia mellifera* and *Acacia senegal* being high in crude protein can be planted by the farmers for various purposes such as poles, fuel wood, timber as well as being used as fodder supplement to livestock.

- Furthermore, farmers should be encouraged to preserve the browse tree leaves for use in dry season by cutting and drying them during wet season where livestock feeds are plenty

5.4 Areas for further study

The findings from the current study conducted on evaluation of conventional chemical composition, mineral concentrations and *in vitro* digestibility of browse tree fodder species indigenous to Kongwa and Kiteto districts provides baseline information for further studies in the same area. The following are the suggested areas for further research:

- Apart from the eight browse species assessed in the current study, more browse species which can be used as livestock fodder should be screened then their nutritive value should be evaluated for them to be fully exploited in the future.
- Evaluation of these eight browse species should extend to determine the levels of phenolics and tannins which appear to limit utilization of most browse tree/shrub species for protein supplementation of low quality roughages.
- Furthermore, mineral contents of the soil and water in the localities where the browse species are found should be assessed.
- Digestibility of the browse species in the current study was determined through *in vitro* technique; further studies can be carried out to determine the *in vivo* digestibility potential of the browse feeds (involving the use of live animals).

REFERENCES

- Abdulrazak, S. A.; Muinga, R. W.; Thorpe, W and Ørskov, E. R (1996) The effects of supplementation with *Gliricidia sepium* or *Leucaena leucocephala* on intake, digestion and live-weight gains of Bos Taurus x Bosindicus steers offered napier grass. *Animal Science* 63: 381-388.
- Abdulrazak, S.A; Fujihara, T; Ondiek,T; Orskov, E.R (2000).*Nutritive evaluation of some Acacia from Kenya*. *Animal Feed science and technology* 85, 89-98.
- Aganga, A.A and Tshwenyane, S.O. (2003), Feeding values and Anti-Nutritive Factors of Forage Tree legumes. *Pakistan Journal of Nutrition*, Vol. 2, No. 3, 170-177.
- Annison,E.F , Bryden, W.L, (1998) *Perspectives on ruminant nutrition and metabolism.In; Metabolism in the rumen*. *Nutritional research review*11, 173-198.
- AOAC.(1990), *Official Methods of Analysis*. Association of Official Agricultural Chemists.15thEd Vol. II. Arlington, Virginia, U.S.A.
- Azim. A, Ghazanfar.S,Latif. A,andNadeem.M.A (2011), “Nutritional Evaluation of Some Top Fodder Tree Leaves and Shrubs of District Chakwal, Pakistan in Relation to Ruminants Requirements”, *Pakistan journal of Nutrition* vol 10,No.1,54-59.
- Conklin-Brittain, N.L and Dierenfeld, E.S. (1996), Small ruminants: digestive capacity differences among four species weighing less than 20 kg, *ZooBiol*, Vol. 15:481–90.
- Cooper, S.M. and Owen-Smith, N (1985). Condensed tannins deter foraging by browsing ungulates in a South African savanna. *Oecologia* 67: 142-146.
- Cooper, S.M. and Owen-Smith, N (1986) Effects. of plant spinescence on large mammalian herbivores. *Oecologia*, 68: 446-455.
<http://link.springer.com/article/10.1007%2FBF01036753#page-1> visited on 11/09/2014.
- Crowder, L.V and Cheddah, H.R. (1982), *Tropical grassland Husbandry*, Longman Inc. New York USA.
- Dierenfeld S. E, Pamela J. M & Mary B. H. (2002), *Duikers: Native Food Composition, Micronutrient Assessment, and Implications for Improving Captive Diets*. Wiley-Liss, Inc. New York, USA.
- Doreau, B. M and Philippe au, C. (1999), Maize silage genotype and ruminant digestion. *Review paper, Zootehnika*, 74-1.

- Dynes, R. A. and Schlink, A. C. (2002), Livestock potential of Australian species of Acacia. 1CSIRO Livestock Industries, Western Australia. Conservation Science West- Australia, Vol. 4, No. 3, 117–124.
- Erickson, D.O, Meyer, D.W and Foster, A.E. (1982), The Effect of Genotypes on the Feed Value of Barley Straws. Journal of Animal Science, Vol. 55, 1015-1026.
- Geren, H.; Kır, B.; Demiroglu, G.; Kavut, Y. T. (2009), Effects of different soil textures on the yield and chemical composition of alfalfa (*Medicago sativa* L.) cultivars under Mediterranean climate conditions., Asian Journal of Chemistry, India. Vol. 21, No. 7, 5517-5522.<http://www.asianjournalofchemistry.com>.
- Goering, H.K and Van Soest, P.J. (1970), Forage fiber analyses (apparatus, reagent procedure and some applications). Agriculture handbook No 379. Agriculture research services, US.
- Gotelli, Nicholas.J. (1995) .primer of Ecology.Sinauer Associates Inc Mass, <http://www.waterstones.com/waterstonesweb/products/nicholas+j+gotelli/a+primer+of+ecology/9608216/> visited on 13/09/2014.
- Gutteridge, R.C. and Shelton, H.M. (1998), Forage Tree Legumes in Tropical Agriculture, Tropical Grassland Society of Australia Inc. Australia grazing lands, p. 329-338.
- Kakengi, V.A.M; Ndabikunze, S.M; Starwatt, S.V and Fujihara, T. (2007), Trace mineral contents of grass and browses in Tanzania and its implication to ruminant feeding and reproduction.” Journal of Food, Agriculture & Environment Vol.5 (1): 210-215.
- Kanuya, N.L; Matiko, M.K; Kessy, B.M; Mgongo, F.O; Ropstad, E and Reksen, O. (2006), A study on reproductive performance and related factors of zebu cows in pastoral herds in a semi-arid area of Tanzania. Vol 65 (9), 1859–1874
- Khanal, R.C. & Subba, D.B.(2001), Nutritional evaluation of leaves from some major fodder trees cultivated in the hills of Nepal, Animal Feed Science and Technology 92, 17-32.
- Kitalyi, A.J and Kabatange, M.A (1986), “Livestock feeding potentials, constraints and possible improvements in the semi-arid areas of Central Tanzania” Tanzania Livestock Research Organization, Mpwapwa.
- Kumara, Mahipala M B P, Krebs G L, McCafferty P and Gunaratne L H P 2009 Chemical composition, biological effects of tannin and in vitro nutritive value of selected browse species grown in the West Australian Mediterranean environment. Animal Feed Science and Technology 153: 303-215.

- Le Houérou, H.N.(1980). Background and justification, p. 3. In: H.N. Le Houérou (ed.), Proceedings of the International Symposium. on Browse in Africa. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.
- Leng, R. A. (1993), Quantitative ruminant nutrition - A green science. Australian Journal of Agricultural Research, Vol. 44, 363-80.
- Leng,R.A. (1990), Factors affecting the utilization of poor quality roughage by ruminants particularl under tropical conditions.Nutrition Research Review, 3: 277-303.
- Leng.R.A.(1997) Tree foliage in ruminant nutrition. FAO Animal production and health.
- Lukuyu.B, Franzel.S,Ongadi.P.M, and Duncan.A.J, (2011) “ Livestock feed resources: Current production and management practices in central and northern rift valley provinces of Kenya” Livestock Research for Rural Development.
- Madibela, O.R., Seitshiro, O. and Mochankana, M.E. (2006), Deactivation Effects of Polyethylene Glycol (PEG) on in vitro Dry Matter Digestibility of Colophospermum mopane (Mophane) and Acacia Browse Trees in Botswana, Pakistan Journal of Nutrition, vol 5 (4):343-347.
- Makkar, H.P.S. & Becker, K. (1996), Nutritional value and anti-nutritional components of whole and ethanol extracted Moringa oleifera leaves. Animal Feed Science Technology 63, 211-228
- Mangan, J. (1988), Nutritional effects of tannins in animal feeds. Nutritional research Review, Vol. 1, 209-231.
- Mbwambo,L. (2000).Status of arid and semi- arid lands of Tanzania.Paper presented at the Drylands Agroforestry Workshop 1st-3rd September 2004,ICRAF Headquarters, Nairobi-Kenya. Livestock Journal of Agricultural Food Chemistry, vol 32, 447-453.
- McDonald, P, Edwards, R.A, Greenhalgh, J.F.D and Morgan, C.A. (1995), Animal Nutrition.Longman, 5th edition, 605.
- McDowell, L. R. (ed). (1992), Minerals in Animals and Human Nutrition. 2nd edn, Academic Press Inclusions, New York.172-202 pp.
- Melagu S, Peters K P and Tegegne A 2003 In vitro and in situ evaluation of selected multipurpose trees, wheat bran and Lablab purpureus as potential feed supplements of tef (Eragrostistef) straw. Animal Feed Science and Technology 108: 159-179
- Menke, K.H and Steingass, H (1988). Estimation of Energetic feeds values obtained from chemical analysis and in vitro gas production using rumen fluid. Animal resource development, Vol: 28, 7-55.

- Minson,D.J.(1990).Forage in ruminants. Academic press Inc.,San Diego, California.USA
- Mokoboki, H.K. (2011), Effect of species within season on techniques used to measure nutritive value and anti-nutritional factors in browse tree leaves. Life Science Journal. Vol. 8, No. 2,112-119.<http://www.lifesciencesite.com> visited on 12/05/2014.
- Mountousis, I, Papanikolaou, K, Stanogias, G, Chatzitheodoridis, F and Karalazos, V. (2006), Altitudinal chemical composition variations in biomass of rangelands in Northern Greece. Livestock Research for Rural Development, Vol. 18, Article No.106.
- Mtengeti, E. J. ;Mhelela, A. (2006). Screening of potential indigenous browse species in semi-arid central Tanzania. A case of Gairo division.Livestock. Research for Rural Development,18 (8): 108 <http://www.lrrd.org/lrrd18/8/mten18108.htm> visited on 07/08/2014.
- Mtui,D.J, Lekule, F.P, Shem , M.N, Ichinohe, T and Fujihara ,T(2009), Comparative potential nutritive value of grasses, creeping legumes and multipurpose trees commonly in sub humid region in the Eastern parts of Tanzania. Livestock Research for Rural Development 21 (10).
- Ndlovu.L.R, Mlambo.L.andDzowela.B.H.(2000) “Chemical composition, phenolic content and *in vitro* gas production constants of forage of psyllid resistant species grown in Zimbabwe” African crop science,vol8 No.1, Pp. 63-73.
- Norton, B.W.(1994).The nutritive value of tree legumes. In: Gutteridge, R. C., Shelton, H.M. (Eds), Forage Tree legumes in Tropical Agriculture. CAB International, Wallingford, UK. 202 – 215 Pp.
- NRC (2001). Nutrient requirement of dairy cattle,7th revised edition, Washington, D.C
- NRC (National Research Council) (1981) Nutrient Requirements ofGoats.No.15.National Academy of Sciences, Washington DC, 91pp.
- NRC 1978 National Research Council. Nutrient requirements of beef cattle. 7th revised edition National Academy of Sciences, Washington, DC, USA.
- NRC. (1984) . Nutrient requirements of small ruminants: sheep, goats, cervids, and new world camelids. National Research Council of the National Academies, Washington DC
- Oba, M, and Allen, M. (2005), *In vitro* Digestibility of Forages, Michigan State University Press, USA.

- Olsson, A .and Welin, S .1989 The potential of local shrub as feed for livestock and mineral content of some soil licks in central Tanzania. Working paper 125. Swedish University of Agricultural Science. International Rural Development Centre, Uppsala. <https://www.google.co.tz/search?tbm=bks&hl=en&q> visited on 16/09/2014
- Ørskov, E. R and Shand, W. J. (1997), Use of the nylon bag technique for protein and energy evaluation and for rumen environment studies in ruminants. The Rowett Research Institute, UK.
- Ørskov, E. R and Ryle, M. (1990), Energy nutrition in Ruminants. Elsevier applied Science, London and New York.
- Osuji, P.O, Odenyo, A.A. (1997), The role of legume forage as supplements to low quality roughage-ILRI experience. Animal Feed Science and Technology, Vol. 69, 27-38.
- Otsyina, R.M. and McKell, C.M. (1985), Africa browses in the nutrition of livestock. Utah State University, Logan, Utah, USA. paper No. 139. FAO,Rome.Pp 45-71.
- Pastor, J., Moen, R. and Cohen, Y. 1997.Spatial heterogenities, carrying capacity, and feedbacks in animal–landscape interactions. – Journal of Mammalogy 78: 1040-1052. www.nrri.umn.edu › NRRI › CWE visited on 20/08/ 2014.
- Provenza, F.D. and Balph, D.F. 1988. Development of dietary choice in livestock on rangelands and its implications for management. – Journal of Animal Science 66: 2356-2368.
- Rubanza ,C .D .K, Shem, M. N, Otsyina, R and Fujihara, T (2005) Performance of Zebu steers grazing on western Tanzania native forages supplemented with *Leucaena leucocephala* leaf meal. Agroforestry Systems.
- Rubanza CDK, Shem MN, Otsyina ER, Ichinohe I, Fujihara ,T (2003). Content of phenolics and tannins in leaves and pods of some Acacia and Dichrostachys species and effects on in vitro digestibility. Journal of Animal Feed Science, 12: 645 – 663.
- Rubanza, C. D .K (1999) The effect of *Leucaena leucocephala* (*Leucaena*) leaf meal supplementation on growth performance of cattle grazing on traditionally conserved forages (Ngitiri). MSc. Dissertation. Sokoine University of Agriculture, Morogoro, Tanzania. P. 140.
- Rubanza, C. D. K, Shem, M .N, Ichinohe, T and Fujihara, T. (2004) Effects of *Acacia nilotica*, *Acacia polyacantha* and *Leucaena leucocephala* leaf meal supplementation on growth performance of Small East African goats fed on native hay basal forages. In: Wong H K, Liang B A, Jelani Z A, Ho Y W, Goh Y M, Panandam J M and Mohamad W Z (editors). Proceedings of the 11th Asian-Australasian Association of Animal Production Society (AAAP) International Congress 5-9 Sept. 2004, Kuala Lumpur, Malaysia. pp. 392-395.

- Rubanza, C.D.K, (2005) Studies on utilization of browse tree fodder supplements to ruminants fed on low quality roughages in north-western Tanzania. PhD Thesis. Tottori University, Japan. pp. 44-47.
- Rubanza, C.D.K, Shem, M.N, Otsyina, R, Ichinohe, T and Fujihara, T. (2003), Nutritive Evaluation of Some Browse Tree Legume Foliages Native to Semi-arid Areas in Western Tanzania. Asian-Australian Journal of Animal Science, Vol. 16, No. 10, 1429-1437.
- Rubanza, C.D.K. (2009), Evaluation of nutritive potential of fodder shrub and tree species native to West Asia and North Africa (WANA) region. Tanzania Forestry Research Institute (TAFORI) TWAS-UNESCO Associated fellow at ICARDA.
- Rubanza,C.D.K, Shem,M.N, Ichinohe,T and Fujihara,T, (2006),Polyphenolics and mineral composition of selected browse tree species leaves native to north western Tanzania traditional fodder banks, Journal of Food, Agriculture and Environment. Vol 4(1) 328-332.
- SAS / Stat view (1999). Using Stat view. Statistical Analytical System (SAS) Inc. third edition.SAS Inc. Cary, NC, USA.288pp.
- Shayo, C.M. (1997), Uses , yield and nutritive value of mulberry (*Morus alba*) tree for ruminants in the semi-arid areas of Tanzania. Tropical grasslands . 31:599-604 pp. .www.tropical-grasslands.info/public/journals. Visited on 22/09/2014.
- Shayo,C.M;Ogle,B and Udén,P. (1996), Water melons (*Citrullus vulgaris*) as the main source of water for cattle in Central Tanzania. Tropical Grasslands, Volume 30, 308–313.
- Skarpe, C., Bergström, R., Bråten, A. L. and Danell, K. 2000. Browsing in a heterogenous savanna.Ecography ,23: 632-640.
- Tilley, J. M. A and Terry ,R. A. (1963), A two-stage technique for the in vitro dry matter digestibility of forage crops. Journal of British Grassland Society, 18: 104-111.
- Upreti, C. R and Shrestha, B. K. (2006), Nutrient Contents of Feeds and Fodder in Nepal, Feedstuff and Animal Production in Nepal. Animal Nutrition Division, NARC Kathmandu, Nepal. www.narc-nepal.org.
- United Republic of Tanzania (2011).Ministry of Livestock and Fisheries Development Livestock Development Sector Programme, Government printers, Dar es salaam, Tanzania.1pp.
- Van Soest, P.J. (1994).Nutritional Ecology of the Ruminant ,2nd Edition. Cornell University Press.

Van Soest, P.J; Robertson, J.B; Lewis, B.A .(1991) Methods for dietary fiber, neutral detergent fiber, and non- starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74: 3583 – 3597.