NUTRITIONAL POTENTIAL OF ACACIA (*Acacia nilotica (L.)* DEL.) PODS FOR GROWING RED SOKOTO GOATS.

BY

CHIKE UGURU
B.SC AGRIC (ED), UNIVERSITY OF NIGERIA, NSUKKA (1991)
M.SC (ANIMAL SCIENCE), AHMADU BELLO UNIVERSITY, ZARIA (2000)

A DISSERTATION SUBMITTED TO THE POST GRADUATE SCHOOL OF AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY OF THE DEPARTMENT OF ANIMAL SCIENCE, FACULTY OF AGRICULTURE AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

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DECLARATION

I declare that this Dissertation was written by me under the guidance/supervision of Professors C.A.M Lakpini, G.N. Akpa and G.S Bawa. It is a product of research work carried out by me. It has not been accepted in any previous application for higher degree. All references and quotations are indicated and the sources of information specifically acknowledged.

Chike Uguru **Date**

DEDICATION

This Dissertation is dedicated to the loving memory of my late senior brother: Signor, Kenneth Ikeokwuadighim Uguru Ukejelam (A.K.A, Merci Mackay); who was a big encouragement and inspiration to me in my quest for academic glory and in other spheres of life.

CERTIFICATION

This Dissertation entitled "Nutritional Potential of Acacia (*Acacia nilotica (L.) Del*.) Pods for Growing Red Sokoto Goats" by Chike Uguru meets the regulation governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

Prof. C.A.M Lakpini. ***(Major Supervisor)*** ***N.A.P.R.I, A.B.U, Zaria.***	**Date**
Prof. G.N. Akpa. ***(Supervisor)*** ***Dean, Faculty of Agriculture,*** ***A.B.U, Zaria.***	**Date**
Prof. G.S. Bawa. ***(Supervisor)***	**Date**
Dr. S. Duru. ***Head of Department Animal Science,*** ***A.B.U, Zaria.***	**Date**
Prof. A.A. Joshua. ***Dean Post Graduate School,*** ***A.B.U, Zaria.***	**Date**

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ABSTRACT

Two separate studies to evaluate alternative methods of processing *Acacia nilotica* pods and level of replacement of cotton seed cake with Acacia pods; and its effect on nutrient composition, feed intake, digestibility of nutrients, heamatological parameters and general performance of Red Sokoto goats were conducted. The aims were to explore cheaper, safer and easier method of processing Acacia pods and to explore the advantages of *Acacia nilotica* pods as a cheaper source of protein to livestock; in place of the highly competitive and costly conventional sources of protein to livestock. Differently processed *A. nilotica* pods contained 96.13%, 96.47%, 97.52%, 97.21% and 98.12% dry matter, 12.69%, 12.13%, 15.06%, 13.25%, and 10.13% crude protein; 2.81%, 2.33%, 5.51%, 9.46%, and 4.74% hemicelluloses, for sun-dried (T_1), crushed (T_2), soaked and milled (T_3), sun-dried and milled (T_4), and sun-dried milled with charcoal (T_5) respectively. Sun-dried Acacia pods contained 0.05% Sodium, 4.00% (mg/kg) Calcium, 0.03% Iron, 0.01% Zinc, 0.14% Magnesium and 1.00% Potassium. Tannin content in differently processed Acacia pods were 1.20, 1.30, 0.90, 0.10 and 0.80 mg/100kg in treatments T_1, T_2, T_3, T_4 and T_5 respectively. Twenty five Red Sokoto goats (bucks) of average age of 10 months and averagedly weighing 10.2 ± 0.4 kg were used in a Completely Randomized Block Design (CRBD) experiment, to evaluate the effect of processing *A. nilotica* pods and dried sweet potato forage (basal diet) on feed intake, nutrient digestibility and performance of Red Sokoto goats. Dietary treatments significantly ($P<0.05$) affected daily feed intake (DFI), feed conversion ratio (FCR), weight gain (WG), and final body weight (FBW). Digestibilities of CP, EE, NDF, and HC were significantly ($P<0.05$) affected across dietary treatments. Nitrogen intake (NI) and faecal nitrogen (FN) differed significantly ($P<0.05$) across dietary treatments. Packed cell volume (PCV), haemoglobin (Hb) and total plasma protein (TPP) were not significantly ($P>0.05$) affected by dietary treatments. However, plasma urea nitrogen (PUN) and creatinine (Cr) differed significantly ($P<0.05$) across dietary treatments. In experiment 2, diets containing sun-dried *Acacia nilotica* pods at different levels contained 94.41%, 94.21%, 93.62%, 93.69%, and 93.21% dry matter, 17.56%, 17.50%, 15.38%, 14.50%, and 14.38 % crude protein; 35.32%, 17.47%, 11.52%, 30.10% and 14.53% hemicelluloses at 0 to 100% inclusion levels respectively. Diets containing sun-dried Acacia pods to replace cotton seed cake and dried sweet potato forage (basal diet) were fed to 25 Red Sokoto goats (bucks) of average age of 10 months; and averagedly weighing 10.3 ± 0.1 kg in a Completely Randomized Block Design (CRBD) experiment, to evaluate the effect of replacing cotton seed cake (CSC) with sun-dried Acacia pods on feed intake, nutrient digestibility, haematological parameters and performance of Red Sokoto goats. Different levels of Acacia pods significantly ($P<0.05$) affected weight gain (WG), daily weight gain (DWG), feed conversion ratio (FCR) and cost per weight gain in Naira per kilogramme (C/WG₦/KG). Digestibilities of DM, CP, EE, CF, NDF, and HC were significantly affected ($P<0.05$) across dietary treatments . Water intake (WI), nitrogen intake (NI), faecal

nitrogen (FN) and urinary nitrogen (UN) differed significantly ($P<0.05$) across dietary treatments. Packed cell volume (PCV), haemoglobin (Hb), total plasma protein (TPP), plasma urea nitrogen (PUN) and creatinine (Cr) differed significantly ($P<0.05$) across dietary treatments. It was therefore concluded that sun-drying Acacia pods was preferred to other methods of processing used in this study because it gave better results in terms of FI, WG, FCR, and FBW. It was also found to be cheaper and easier to process. It was also concluded that 25% of sun-dried Acacia pods can be used to replace CSC in the diets of Red Sokoto goats without having any adverse effect on nutrient digestibility, haematological parameters and performance in them. Therefore, weight loss amongst Red Sokoto goats can be highly reduced by incorporating Acacia pods in their diets; especially during periods of feed scarcity, which is a common experience in the Northern part of Nigeria.

TABLE OF CONTENTS

Title	page
Title page - - - - - - - - - -	i
Declaration - - - - - - - - - -	ii
Dedication - - - - - - - - - -	iii
Certification - - - - - - - - - -	iv
Acknowledgment - - - - - - - - - -	v
Abstract - - - - - - - - - -	vi
Table of contents - - - - - - - - - -	viii
List of figures - - - - - - - - - -	xiii
List of tables - - - - - - - - - -	xiv
List of appendices - - - - - - - - - -	xvi
List of acronyms - - - - - - - - - -	xvii
CHAPTER ONE	
1.0 Introduction - - - - - - - - - -	1
1.1 Justification of the Study - - - - - - - -	3
1.2 Objectives of the Study - - - - - - - -	3
1.3 Research Hypotheses - - - - - - - -	4
CHAPTER TWO	
2.0 Literature Review - - - - - - - - -	5
2.1 Use of browse plants in feeding ruminants - - - - -	5
2.2 *Acacia nolitica* as a browse plant - - - - - -	6
2.2.1 Chemical Composition of *Acacia nilotica* - - - - -	7

2.2.2 Nutrient Levels in *A. nilotica* Leaves and Fruits - - - - 8

2.2.3 Factors militating against the use *A. nilotica* in feeding livestock - - 9

2.2.4 Effects of *A. nilotica* on performance of livestock - - - - 12

2.2.5 Ways of improving the use of *A. nilotica* in livestock nutrition - - 13

2.2.6 Anti-nutritional factors in *Acacia nilotica* - - - - - 14

2.2.7 Effects of tannins on the nutritional value of browse plants - - - 15

2.2.7.1 Reduction in digestibility of feeds amongst species - - - - 16

2.2.8 Positive effects of tannins - - - - - - - 20

2.2.9 Effect of tannin on gas production - - - - - - 24

2.3 The use of sweet potato forage in livestock production - - - 25

2.3.1 Use of sweet potato in livestock feeding - - - - - 25

2.3.2 Nutritional values of sweet potato forage - - - - - 26

2.3.3 Advantages of sweet potato over other root crops - - - - 27

2.3.4 Ways of processing sweet potato and benefits of processing- - - 27

2.3.5 Necessary guides for effective use of sweet potato forage - - - 29

2.4 Microbial digestion in ruminants - - - - - - 29

2.4.1 Limitations of cell wall digestion by rumen micro organisms - - 31

2.4.2 Evaluation of forage digestion by gas production - - - - 33

2.5 Volatile fatty acids - - - - - - - - 35

CHAPTER THREE

3.0 Materials and Methods - - - - - - - 37

3.1 Experiment I: Collection, Processing and Evaluation of *Acacia nilotica* Pods and Sweet Potato Forage - - - - - - - - 37

3.1.1 Experimental Site - - - - - - - - 37

3.1.1.1 *Acacia nilotica* (L.) Del Pods - - - - - - 37

3.1.2 Sweet potato forage - - - - - - - - 38

3.2 Growth Study - - - - - - - - 38

3.2.1 Proximate and Chemical Analyses of feeds - - - - - 38

3.2.1.1 Feeding Trial - - - - - - - - - 39

3.3 Blood Collection - - - - - - - - 40

3.4 Digestibility trial and Nitrogen Balance - - - - - 41

3.5 Experiment II: Feeding Trials with sun-dried *Acacia nilotica* Pods - 42

3.5.1 Experimental Site - - - - - - - - 42

3.5.2 Growth study - - - - - - - - - 43

3.5.2.1 Proximate and Chemical Analyses of feeds - - - - - 43

3.5.2.2 Feeding Trial - - - - - - - - - 43

3.6 Blood Metabolites - - - - - - - - 45

3.6.1 Procedure for blood collection - - - - - - 45

3.7 Digestibility trial and nitrogen balance - - - - - 45

CHAPTER FOUR

4.0 Results - - - - - - - - - 47

4.1 Collection, Processing and Evaluation of Acacia pods and sweet potato forage 47

4.1.1 Proximate and chemical composition of experimental diets - - - 47

4.1.2 Feed Intake and growth performance - - - - - 53

4.2 Nutrient Digestibility and Nitrogen Retention - - - - 54

4.3 Blood Metabolites - - - - - - - - 57

4.4 Experiment II: Feeding Trials with sun-dried *Acacia nilotica* Pods (preferred processing method) as a replacement for CSC in goats diets - - - - 58

4.4.1 Proximate and Chemical Analyses - - - - - - 58

4.4.2 Performance of Red Sokoto Goats Fed diet containing different levels of Sun-Dried *Acacia nilotica* Pods as replacement for CSC - - - - 59

4.4.3 Nutrient Digestibility and Nitrogen Retention - - - - 60

4.4.4 Blood Metabolites - - - - - - - - 63

CHAPTER FIVE

5.0 Discussion - - - - - - - - - 73

5.1 Feeding trial - - - - - - - - - 73

5.1.1 Feed ingredients - - - - - - - - 73

5.1.2 Proximate and energy content of feed ingredients - - - 73

5.1.3 Mineral content of feed ingredients - - - - - 74

5.1.4 Tannin in *A. nilotica* pods - - - - - - - 74

5.1.5 Feed intake - - - - - - - - - 75

5.1.6 Weight changes and feed efficiency - - - - - - 76

5.2 Nutrients digestibility and nitrogen balance - - - - - 76

5.3 Blood Metabolites - - - - - - - - 78

5.3.1 Haematological Parameters of goats in Expt. I - - - - 78

5.3.2 Haematological Parameters of goats in Expt. II - - - - 79

CHAPTER SIX

6.0 Conclusion and Recommendation - - - - - - 80

6.1 Conclusion - - - - - - - - - - 81

6.2 Recommendations - - - - - - - - - 81

References - - - - - - - - - - 82

Appendix - - - - - - - - - - 96

LIST OF FIGURES

Figure Page

Fig 1: Trend of PCV (%) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different days of collection - - - - 63

Fig 2: Trend of Hb (g/dl) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different days of collection - - - - 64

Fig 3: Trend of TPP (g/dl) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different days of collection - - - 65

Fig 4: Trend of PUN (Mmol/l) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different days of collection - - - - 66

Fig 5: Trend of CR (µmol/l) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different days of collection - - - 67

Fig 6: Trend of PCV (%) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different hours of collection - - - 68

Fig 7: Trend of Hb (g/dl) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different hours of collection - - - 69

Fig 8: Trend of TPP (g/dl) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different hours of collection - - - 70

Fig 9: Trend of PUN (Mmol/l) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different hours of collection - - - - 71

Fig 10: Trend of CR (µmol/l) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different hours of collection - - - 72

LIST OF TABLES

Table		Page
Table 2.2.2	Nutrient Levels in *A. nilotica* leaf and fruit - - - -	8
Table 3.1:	Composition of Experimental diets used for the 1st feeding trial -	38
Table 3.2:	Composition of experimental diets containing varied levels of *A. nilotica* pods - - - - - - -	44
Table 4.1:	Chemical Composition of *Acacia nilotica* pods processed in different ways and Sweet potato forage - - - - - - - - -	48
Table 4.2:	Mineral Contents of Dried *Acacia nilotica* Pods - - -	50
Table 4.3:	Anti-Nutritional Factors (ANF) in the Differently Processed *Acacia nilotica* Pods, and dried Sweet Potato Forage - - - - -	50
Table 4.4:	Chemical Composition of experimental diet containing differently processed *A. nilotica* Pods (Expt. I) - - - - - -	51
Table 4.5:	Performance of Red Sokoto Goats Fed diets containing Differently Processed *Acacia nilotica* Pods - - - - - - -	53
Table 4.6:	Nutrient Digestibilities and nitrogen Balance in Red Sokoto Goats Fed diets containing differently processed *Acacia nilotica* Pods and Sweet Potato Forage - - - - - - -	55
Table 4.7:	Effects of differently processed *Acacia nilotica* pods on Blood Metabolites of Red Sokoto Goats - - - - - - - -	56
Table 4.8:	Chemical Composition of diets Containing different levels of sun-dried *Acacia nilotica* pods as replacement for CSC (Expt. II) - - -	58

Table 4.9: Performance of Red Sokoto Goats Fed diets containing different Sun-Dried *Acacia nilotica* Pods to replace CSC - - - - 59

Table 4.10: Nutrients Digestibilities and Nitrogen Balance in Red Sokoto Goats Fed different levels of sun-dried *Acacia nilotica* Pods as replacement for CSC - 61

LIST OF APPENDICES

Appendix		Page
Appendix 1:	Baseline information of the experimental Animal - -	96
Appendix 2:	Calculated metabolizable energy ME (Kcal/kg) of experimental diet I	99
Appendix3:	Calculated metabolizable energy ME (Kcal/kg) of experimental diet II	100
Appendix 4:	Calculated costs of experimental diets II - - - -	101
Appendix 5:	Blood sampling at the beginning, Middle and end of Experiment	102
Appendix 6:	Effects of different times of blood sampling on blood metabolites in Red Sokoto goats fed different level of *A. nilotoca* pods - - - -	103

LIST OF ACRONYMS/SYMBOLS

ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
ANFs	Anti-Nutritional Factors
Ca:	Calcium
CTE	Condensed Tannin Extracts
CF:	Crude Fibre
Cl	Chlorine
CP	Crude Protein
Cr	Creatinine
CSWRI:	Central Sheep and Wool Research Institute, India
CT	Condensed Tannins
DGB	Dried Brewers Grain
DM	Dry Matter
DNA	Deoxy-Ribonucleic Acid
EE	Ether Extract
Fe	Iron
FEC	Faecal Egg count
GIN	Gastro Intestinal Nematodes
GIT	Gastro Intestinal Tract
Hb	Haemoglobin
HT	Hydrolysable Tannins
K	Potassium
ME	Metabolizable Energy
Mg	Magnesium

Mn	Manganese
Na	Sodium
NDF	Neutral Detergent Fibre
NDIN	Neutral Detergent Insoluble Nitrogen
NFE	Nitrogen Fibre Extract
NRC	National Research Council
OMD	Organic Matter Digestibility
P	Phosphorous
PA	Protanthocyanidins
PCV	Packed cell volume
PEG	Polyethylene Glycol
pH	Reaction (Acidic or Alkalinity value)
PRPs	Proline Rich Proteins
PUN	Plasma Urea Nitrogen
PVP	Polyviny polyueriolidone
RNA	Ribo Nucleic Acid
S	Sulphur
SCFA	Short chain Fatty Acid
Si	Silica
TPP	Total Plasma Protein
VFA	Volatile Fatty Acid
WT	Wattle Tannin
Zn	Zinc

CHAPTER ONE

1.0 INTRODUCTION

The most difficult constraint in small ruminant production in the tropics is the inadequacy and poor quality of the available energy and protein feedstuffs particularly during the dry season (Olafadehan *et al.* 2009). During critical periods, available forages do usually contain low energy and protein content and this affects voluntary intake and digestibility leading to loss of weight amongst the animals. In addition to the above, prohibitive cost of conventional feed stuffs because of competition with man and monogastrics also stand as a militating factor to the realization of the full potential of small ruminant production (Njoya *et al* ., 2005)

The impact of inadequacy of livestock feed in the dry season especially protein is a major constraint to successful livestock production in many parts of the tropics. The above prevailing condition justifies efforts towards sourcing for alternative and locally available means of feeding ruminants to increase their productivity while contending with the problem of insufficient conventional feed resources. According to Ademosun (1985) and Topps (1992) attention of ruminant nutritionists in recent years has shifted to cheaper and locally available alternative feedstuffs which should be nutritionally viable, non-toxic and of little or no dietary value in human diets.

Acacia species are indigenous woody browse legumes found in semi-arid and arid areas of tropical and sub-tropical countries (NRC, 1979). *Acacia nilotica (L.) Del* is a thorny wattle native to India, Pakistan and many countries in Africa. In Africa and the Indian sub- continent they are extensively used as a browse, timber and fire-wood (Gupta, 1970; Mahgoub 1979; New 1984). They are also used for tanning, medicinal aphrodisiac and for forestry or reclamation of degraded land (Purl and Khybri, 1975; Shetty 1977). In Asia and Africa, Acacia plants and seed

pods are eaten by domestic animals such as cattle, sheep, goats and camels. It is the view of many researchers that Acacia species can be more profitably used in the feeding of livestock. According to Sawe *et al.* (1998) goats supplemented with leaves or pods of *A. brevispica, A. tortilis and A. nilotica* grew faster than the unsupplemented controls. In the same vein, studies by ILCA(1988) and (1989); and Tanner *et al.* (1994) revealed that pods of some Acacia species, such as *A. tortilis and A. albida,* as well as leaves of *A. brevispica,* when given as supplements to poor quality roughages, give live-weight gains in livestock comparable with those feed oil seed cake or Lucerne (*Medicago sativa*).

Acacia species are widely distributed in tropical and sub-tropical Africa from Egypt and Mauritania to South Africa. They can grow on different types of soil ranging from clay to sandy loam soils. It commonly grows close to waterways on seasonally flooded river flats and tolerates salinity well. Acacia species can thrive in areas receiving less than 350mm of rainfall to areas receiving more than 1,500mm per annum. In Nigeria, *Acacia nilotica species*, popularly known as Bagaruwa is widely grown in the northern part of Nigeria such as Kano, Yobe, Borno, Kebbi, Katsina states etc; where they cover large kilometers of land mass.

Notwithstanding the availability of *A. nilotica* and its potentials for feeding livestock, its use in feeding livestock is still very limited. Its major use is for leather tanning, and to a lesser extent for treatment of some diseases and for control of erosion in the desert prone areas. A major limitation to the use of Acacia species is the presence of an anti-nutritional factor known as tannin.

According to Kumar and D' Mello (1995) tannins hinder the availability of protein in Acacia species to rumen microbes and consequently affect dry matter (DM) intake and

digestibility. However, other authors reported that the effects of tannins may be both positive (Ben Saleem et al 1999), and negative (Degan *et al*., 1998; Maasdorp *et al*; 1999).

Poage *et al.* (2000), reported that charcoal and some chemical treatment are useful in detannifying feeds with anti-nutritional factors. Interestingly, the pods of *A. nilotica* have the least percentage of tannins 5.4% as against 7.6%, 13.5% and 15.8%, respectively for the leaves, bark and twigs (Kumar, 1983; Ehoche *et al;* 1983; Reed 1986., Tanner *et al*; 1994).

1.1 JUSTIFICATION OF STUDY:

Inadequacy of livestock feeds in the dry season particularly protein is a major constraint to livestock production in the tropics. Acacia species, such as *A.nilotica* are found in most tropical countries. They have a relatively high crude protein ranging from 12 to 30%. Notwithstanding, their availability and potential as an alternative source of protein to livestock, they are mainly used for tanning of leather, as medicine and for reclamation of degraded lands. This study attempts to explore the possibility of using *A. nilotica* pods in feeding Red Sokoto goats.

1.2 OBJECTIVES OF THE STUDY:

The objectives of this study are to:

- Determine the chemical composition and anti-nutritional factors (ANFs) contained in differently processed *A. nilotica pods*.
- Assess the nutritional value of *A. nilotica pods* processed in different ways.
- Determine the performance of Red Sokoto goats fed graded levels of the selected / preferred *A. nilotica pods* as replacement for cotton seed cake.

In addition, this study on completion will generate information on the use of *A. nilotica pods* in small ruminants feeding. This will add to the body of existing knowledge in livestock nutrition. It will also be of great value to students, researchers and livestock farmers.

1.3 RESEARCH HYPOTHESES:

For this study, the following null hypotheses are postulated:

Ho_1 The levels of anti-nutritional factors (ANF_S) in *A.nilotica* pods is beyond the tolerable levels for Red Sokoto goats.

Ho_2 Processing *A. nilotica* pods in different ways will not have effect on their nutritional value, intake, digestibility and performance of Red Sokoto goats.

Ho_3 Feeding graded levels of *A. nilotica* pods as replacement for cotton seed cake will not have significant effect on cost of production in Red Sokoto goats.

Ho_4 Feeding graded levels of processed *A. nilotica* pods will not have any effect on intake of nutrients, digestibility and performance of Red Sokoto goats.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 USE OF BROWSE PLANTS IN FEEDING RUMINANTS:

Browse has been defined as the leaves and sprouts including tender twigs and stems of woody plants which are cropped to a varying extent by domestic and wild animals (Gutteridge and Shelton, 1994). They include the fruit, pods and seeds which provide valuable feed, especially if the tree is deciduous. They are very important in livestock farming; hence some authors have observed that in some arid and semi-arid climates, livestock would not exist without browse plants to supply feed.

Browse plants have many advantages as far as livestock production is concerned. They are less subject to seasonal variation. They can serve as the only feeding stuff to keep livestock in healthy and fair condition. However, they are not adequate as a sole feeding stuff for high producing species (Crowder and Cheddar, 1982). Browse plants are also very palatable and can offer considerable potentials as feeds to livestock (Yahaya *et al*, 2000). The pods and leaves of leguminous browse plants like *Gliricidia sepium, Leucaena leucocephala* are rich in protein, minerals and vitamins. This may be the main reason why traditional herdsmen and other pastoral groups often prune their trees, to produce twigs leaves and pods for their livestock during the dry season, when there is shortage of forages.

Also compared to grasses leguminous browse plants have both higher digestibility and higher intake than grasses and their nutritive value tends to remain higher as they mature. They are also useful in enhancing the sustainability of farming systems because they usually live long and require low maintenance cost than other species. Browse plants can be useful in stabilizing slopy lands against erosion and other agents of denudation because of their deep – rooted nature.

They can be used to improve soil fertility by supplying nitrogen – rich mulch for cropping systems. They can be used to rehabilitate and colonize adverse environments not useful to other crop species, example soils in saline or arid locations. Tall growing browse trees can provide timber and firewood for both domestic and industrial uses. In addition, they can provide life fences, shades trees for plantation crops; they also serve as life trellies for climbing crops. Some browses are used as good sources of fruits and vegetable for man.

2.2 *ACACIA NILOTICA* AS A BROWSE PLANT

In Africa and the Indian sub-continent, *A. nilotica* is extensively used as a browse plant, for timber or firewood (Gupta, 1970; Mahgoub, 1979; New 1984). Like other leguminous browse plants they are often used as buffer crops to overcome feed gaps that arise from seasonal fluctuations in the productivity of other feed resources. They can be relied upon for good supply of green forage rich in protein, minerals and vitamins even in dry season or in times of drought.

In many parts of Africa sheep, cattle and goats actively seek the leaves and stems of *A. nilotica.* Goats, and to a lesser extent sheep also eat the bark of young trees while sheep eat fallen flowers of *A. nilotica.* During the dry season characterized by drought, land owners do cut trees of *A. nilotica* or lop their branches to provide extra feed materials to their livestock.

A. nilotica is not only used as browse plant; the seeds and pods are also incorporated into the feeds of livestock. According to Gupta (1970), in Asia and Africa the plant and the whole pods of Acacia are used to feed domestic animals like cattle, sheep, goats and camels. *A. nilotica* leaves and pods have been used by researchers and stock owners as a supplement to poor quality roughages resulting in appreciable live-weight gains (Tanner *et al.* 1994; Sawe *et al.* 1998).

2.2.1 Chemical Composition of *Acacia nilotica:*

Differences exist in the nutrients contained in *A. nilotica* leaf and fruit as well as the anti-nutritional factors contained in the above parts. Condensed tannins are high in all browsed components. The relative tannin levels in *A. nilotica* from least to most are pods (5.4%), leaves (7.6%), bark (13.5%) and twigs (15.8%). Total polyphenolics in the fruit range from 32 to 34% (Kumar 1983) and in leaf range from 30 to 60% (Ehoche *et al.* 1983, Reed 1986, Tanner *et al.* 1994).

The overall nutritional values of *Acacia nilotica* is difficult to evaluate as the parts browsed by the animals or lopped for fodder include variable proportions of leaves, petioles, twigs, shoots, flowers and pods at various stages of maturity. The composition of these materials, and particularly their amount of fibre and tannins, is also quite variable.

Acacia nilotica leaves and browse are not very rich in protein (about 14%, in the 10-20% DM range) but not very fibrous either (ADF 18% in the 10-30% DM range with some recorded values over 30% DM) . The pods are slightly poorer in protein (about 12%, in the 10-14% DM range) and contain more fibre (ADF 21%, 17-27% DM). The seeds contain much more protein (19%DM) and fibre (29% DM). However, the amount of tannins can be extremely important, both in the leaves (up to 25% total extractable tannins and 5% condensed tannins; Rubanza *et al.*, 2005) and in the pods, where the content in soluble phenolics is particularly high. These phenolics tend to reduce the palatability and feeding value of *Acacia nilotica* browse and pods (Ngwa *et al.*, 2002; Mlambo *et al.*, 2008). The presence of large amounts of tannins can also give rise to artificially high fibre contents (Mlambo *et al.*, 2008)

The nutrient contents of *A. nilotica* leaf and fruit is summarized in the following table.

Table 2.2.2 Nutrient Levels in *A. nilotica* leaf and fruit

	Leaf		**Fruit (pod and seed)**	
Parameter	Mean ± SD	Samples	Mean ± SD	Samples
Crude Protein (%)	13.92 ± 2.53	29	12.30 ± 2.03	28
Fat (%)	6.63 ± 3.41	13	1.93 ± 1.14	23
NFE (%)	60.99 ± 3.41	19	63.68 ± 7.35	22
CF (%)	10.35 ± 2.85	13	15.36 ± 5.85	23
ADF (%)	20.38 ± 6.35	8	25.44 ± 4.16	2
Ash (%)	9.29 ± 2.95	22	5.26 ± 1.29	23
Tannin (%)	7.62 ± 1.00	13	5.45 ± 1.48	2
Lignin (%)	6.95 ± 2.17	6	-	-
P (%)	0.23 ± 0.22	15	0.26 ± 0.21	18
Ca (%)	2.53 ± 1.13	15	0.64 ± 0.19	18
Mg (%)	0.18 ± 0.08	11	0.13 ± 0.02	70
Na* (%)	<0.32	5	<0.01	4
K (%)	1.25 ± 0.79	9	1.28 ± 0.22	5
Si (%)	0.45 ± 0.47	4	0.24 ± 0.21	9
S (%)	0.26 ± 0.03	4	0.59 ± 0.11	2
Cl (%)	0.70 ± 0.26	3	0.36 ± 0.04	2
Cu (mg/kg)	-	6	6.43 ± 0.90	4
Zn (mg/kg)	25.63 ± 9.20	4	28.50 ± 9.76	2
Mn (mg/kg)	90.25 ± 19.00	4	26.50 ± 0.71	2
Fe (mg/kg)	428 ± 205	4	100.00 ± 86.27	2
ME (mg/kg)	8.69 ± 1.09	9	10. 19 ± 0.16	2
OMD (%)	69.9 ± 5.20	3	67.2	1

**** Some values below limit of detection (0.05%)***

NFE = nitrogen free extract.
Fat = ether extract
ADF = acid detergent fibre
CF = crude fibre
OMD = organic matter digestibility
ME = metabolisable energy.

(In: Acacia nilotica: a Tree legume out of control, p7-8; http://www.fao.org/ag/AGPC/doc/publicat Gutt-shel/x5556eov - -)

2.2.3 Factors militating against the use *A. nilotica* in feeding livestock:

Even though *A. nilotica* can produce reasonable quality browse, its use in feeding livestock is limited by the high levels of tannins contained in them. According to Osagie (1998) the ability of the leaves, pods and edible twigs of shrubs and trees as feeds resource for animals is limited by the presence of anti-nutritional factors (ANFs). Anti- nutritional factors may be defined as those substances generated in natural feed stuffs by the normal metabolism of species and by different mechanisms like inactivation of some nutrients, diminution of the digestive process or metabolic utilization of feed; they exert effects that do not favour optimum nutrition. According to Harborne (1989) plants contain ANFs as a way of storing nutrient or as a means of defending their structure and reproductive elements. ANFs contain 'allelochemicals' which are not lethal to species but they can cause low productivity in species and can be toxic to animals if consumed in large quantities, especially during feed scarcity and when animals are confined.

The following ANFs have been implicated as causing limitation in the utilization of shrub and tree forages: non-protein amino acids, glycosides, phyto-hemagglutins and polyphenolics. Tannins are of great importance in the use of acacia species in feeding livestock

Phytohemagglutins:

Other wise known as lectins they are proteins which agglutinate red blood cells. They occur in some important fodder trees, the highest concentrations of lectins are found in seeds, while their concentration in leaves is low due to translocation. Lectins have affinity for sugars and they may also bind carbohydrate moieties of cells of the intestinal wall to cause a non-specific interference with nutrient absorption (Liener, 1985). Fodder trees contains the lectins robin and ricin. Robin, a lectin from *Robinia pseudo-acacia,* has been reported to cause symptoms of anorexia, lassitude, weakness and posterior paralysis in cattle (Cheeke and Shull, 1985). Ricin occurs in castor beans (*Ricinus communis*) which have been reported to cause

poisoning in all class of livestock. Due to ricin, de-oiled castor seed cake (CP 35%) is seldom used as a livestock feed. However, the mature leaves of *R. communis* have been found suitable for feeding sheep (*Behl et al. 1986).* Generally precaution should be taken while feeding castor bean meal to avoid contamination. According to Rao *et al*. (1988) castor bean meal can be detoxified by autoclaving at 20 psi for 60 minutes before incorporating it in sheep diets.

Tannins:

They are water soluble phenolic compounds with a molecular weight greater than 500 and have the ability to precipitate proteins from aqueous solution. They occur almost in all vascular plants. Hydrolysable tannins and condensed tannins (*proanthocyanidins)* are two different groups of phenolic compounds. Generally, tree and shrub leaves contain both types of tannins. The two types differ in their nutritional and toxic effects. The condensed tannins have a more profound digestibility-reducing effect than hydrolysable tannins, whereas the latter may cause varied toxic manifestation due to hydrolysis in rumen. Sheep ingesting 0.9g hydrolysable tannins kg/body weight showed signs of toxicity in 15 days. According to Tanner *et al* (1990), condensed tannin (CT) in *A. nilotica* pods resulted in low growth rate, reduced nitrogen and neutral detergent fibre (NDF) digestibility in sheep. In goats, cases of lethal poisoning when high levels of tannin was fed has been reported in South Africa. According to Carter (2007) all parts of Acacia plant contains high levels of tannins that may hamper protein digestibility and animal performance. Symptoms of poisoning with tannin include abortions, dyspnoea, tachycardia, methyglobineamia, ruminal atony and hyperglycaemia. Terblanche *et al* (1967) cited by Mlambo *et al* (2008), recommended that caution be exercised when feeding *Acacia nilotica* pods to goat on a daily basis. Mlambo *et al* (2008) however, noted that the measurement

and nutritional interpretation of phenolics and tannins content in Acacia species are particularly difficult.

Some animals like Mule, deer, Rats and Mice have been shown to secrete proline-rich proteins in saliva which constitute the first line of defence against ingested tannins. The mechanism of dietary effects of tannins may be understood by their ability to form complex with proteins. Tannins may form a less digestible complex with dietary proteins and may bind and inhibit the endogenous protein, such as digestible enzymes (Kumar and Singh, 1984). Tannin-protein complexes involve both hydrogen-bonding and hydrophobic interactions. The precipitation of the protein-tannin complex depends on pH, ionic strength and molecular size of tannins. Both the protein precipitation and incorporation of tannin phenolics into the precipitate increase with the increase in molecular size of tannins (Kumar and Horigome, 1986). However, when the molecular weight is very large (>5000), the tannins become insoluble and lose their protein precipitating capacity and degree of polymerization becomes imperative to assess the role of tannins in ruminant nutrition (Kumar, 1983; Lowry, 1990).

Dietary condensed tannins may have beneficial effect in ruminants. According to Barry (1987) at 2-3% of inclusion dietary condensed tannins exert beneficial effect by reducing the wasteful protein degradation in the rumen by the formation of a protein-tannin complex. The complex appears to dissociate post-ruminally at a low pH where, presumably, the protein becomes available to form a complex with digestive enzymes such as pepsin and also with the protein of gut wall. Condensed tannins of *Prosopis cineraria* precipitate pepsin at pH 2.0 and the net effect of the presence of condensed tannins may therefore be negligible.

Deleterious effects of tannins can be overcome by using different methods of treatment (Kumar and Singh, 1984). Alkali treatments include ferrous sulphate and polyethylene glycol-

4000 (PEG-4000). The latter was found to be effective for deactivation of tannins in tree leaves (CSWRI, 1987-89). However, using PEG-4000 in routine feeding may not be economical. The use of urea to overcome the deleterious effects of tannin maybe of better practical value. In a study, Russell and Lolley (1989) reported that feeding *P. cineraria* leaves and *Cenchrus spp* for three months at 50:50 basis with 1% urea was enough to maintain adult sheep. In such a feeding system, urea provided extra nitrogen to the animals and also helped to deactivate the tannins in the leaves.

2.2.4 Effects of *A. nilotica* on performance of livestock:

High levels of tannins in plant parts may bind protein and, at high levels suppress animal production. Bullocks fed 45% oil extracted seeds of *A. nilotica* in their diet showed reduced weight gain (68g/day to 16g/day) and a 5% decrease in intake (Pande *et al*., 1982) *A. nilotica* tannins have been used to treat cotton seed cake to prevent rumen degradation of protein. Ehoche *et al*, (1983) reported that at 5% inclusion, tannin can increase live weight gains of lambs by 36%, feed intake by 6%. They also observed that when inclusion level was raised to 10%, average daily gain was reduced by 18% and intake reduced by 4%. Tanner *et al* (1990) reported that sheep fed *A. nilotica* pods and roughage at 204 and 347g/day respectively had lower growth rates than control feeds. Hove *et al*. (2001) also reported that animals fed diets containing tannin tend to drink more water than those fed with low tannin based diet. The increased water intake could be to detoxify the effects of the tannin. Makaranga (2002) also reported a reduction of dry matter (DM) intake and crude protein intake (CP) in sheep fed browse diet containing tannins.

The negative effects of tannins in livestock feeding include: reduction in feed intake because of dryness in the mouth of animals (Lowry, 1990); binding of proteins in feeds (Barry, 1985), adverse effects on digestive enzymes which hinder the availability of nutrients for

productive purposes (Reed, 1986), and reduction of growth in species (Pander *et al* 1982 and Bennick, 2002).

2.2.5 Ways of improving the use of *A. nilotica* in livestock nutrition:

According to Mokoboki *et al*. (2005), the use of Acacias has been limited by paucity of information on the amount and types of tannins they contain. Acacia species can be an invaluable source of protein for strategic supplementation with a better understanding of their tannin properties and proper management.

Steyn, (1934), and Timberlake, (1980) indicated that toxicity of browse plants can be reduced by: Boiling the pod in water, milling the pods, and by mixing them with sulphur or molasses.

Aganga *et al*. (1998) reported that the digestibility of the seeds of Acacia species could be improved by coarsely crushing them if used as supplementary feeds.

Other ways of tackling the problem of negative effects of tannins are feeding a mixture of supplements with readily available nitrogen to dilute the tannin anti-nutritional activity (Rubanza *et al* 2003[a]), Sun-drying the foliage to reduce the tannin content (Rubanza *et al* 2003[a], Ebong, 1995) and by soaking pods with polyethylene glycol (PEG). This has been shown to increase significantly in vitro gas production and 95-h organic matter degradability from 69 to 79%. Pods can also be treated with alkaline or ammonia (NaoH or NH_3) solutions. Here pods are crushed, and soaked in wood ash solution (an alkaline material) in order to reduce tannins contained in the pods. This method of processing using either sodium hydroxide or ammonia can be dangerous (Sikosana, 2006). Also, Mlambo *et al.* (2001) reported that the use of polyethylene glycol (PEG) in processing Acacias may be too costly for small-holder farmers. Poage *et al* (2000) reported that charcoal can be added to Acacia pods to enhance their use in feeding livestock.

2.2.6 Anti-nutritional factors in Acacia nilotica:

Kaitho *et al*., (1998) reported that most browses and forage legumes are known to contain simple or complex phenolic compounds. Tannins are phenolic compounds that precipitate proteins. They are composed of a very diverse group of oligomers and polymers. The differences in the response of animals to legume plants when fed as protein supplements depends on the level of phenolic compounds they contain (Wiegand *et al*., 1995). Anti- nutritional factors in browse plants can cause the following problems to animals, toxicity : reduction in palatability and/ or reduction of feed digestibility. According to Kumar and Singh (1984) further studies are needed to pin point the components of anti-nutritional factors responsible for reduced palatability. Presently, polyphenolics, cyanogens, saponins, non-protein amino acids, phytochaemagglutamins (lecitin), alkaloids, triterpense and oxalic acids are implicated as anti-nutritional factors responsible for reduced palatability and intake of browse plants by ruminants.

Tannins can be divided into two main groups viz condensed tannins (CTS) and hydrolysable tannins (HTS). The condensed tannins are polymers of flavonol units most frequently linked at C4-C8 or C4-C6. They interfere with intake and digestion of the feeds in which they occur (Dube *et al*., 2001) at high levels; but at very low levels most have beneficial effects (Foo *et al*., 1996) Barry and Duncan (1984) suggested the ideal condensed tannin concentration for ruminants to be in the range of 20-40g/kg dry matter, based on the butanol – HCL method.

Hydrolysable tannins (HTS) on the other hand are esters of sugar, usually glucose and a phenolic acid such as gallic acid in gallotannins and hexahydrodiphenic acid in ellagitannin. The hydrolysable tannins are known to be toxic to ruminants (Dollahite *et al* 1962; Holliman, 1985; Shi, 1998). They may also exert inhibitory effects on various enzymes (Yoshiada *et al*; 2000). *A.*

nilotica species has considerable content of hydrolysable tannins (HT) and they are known to be toxic to ruminants. Tannins are found mainly in vacuoles or surface wax of plants. In these sites they do not interfere with plant metabolism. They can act and have metabolic effects only after cell breakdown and death. Tannins are found in the following browse plants and trees: Acacia species, *Quebracho*, Myrobalan, Mangrove, Eucalyptus species (Myrtle), Canaigre, Oak Tree, Maple, Pine tree, Sorghum species etc.

2.2.7 Effects of tannins on the nutritional value of browse plants:

Tannins are complex polyphenolic compounds with great structural diversity which can be present in browse plants and they influence digestibility of protein in the browse plants. Kumar and D'Mello (1995) reported negative effects of tannins on the availability of protein in Acacia species to rumen microbes, by hindering dry matter intake and digestibility. Other authors, Ben Saleem *et al* (1999) and Degan *et al* (1998); Maasdorp *et al* (1999) reported that the effect of tannins may be both positive and negative.

Mokoboki *et al* (2005) observed that voluntary intake of feed may be affected when trees containing high levels of tannins are fed to animals. This is because such trees and shrubs tend to have a low dry matter degradability and therefore a low voluntary intake amongst ruminants.

According to Getachew *et al*, (2000) during disintegration of plant material, such as chewing by ruminants, tannins interact with salivary glycoprotein to form insoluble tannin protein complexes. This may encourage further binding to protein in the rumen at the pH of 5.5-7.2.

Tannins may reduce intake by decreasing palatability and by negatively affecting digestion. Palatability is reduced because tannins are astringent. That is the sensation caused by the formation of complexes between tannins and salivary glycoproteins (Getachew *et al*, 2000)

The form in which forage is fed may influence how tannins affect feed intake. Forages rich in tannins are eaten in larger amounts when field dried rather than fresh frozen. Drying reduces the solubility of tannins and, hence, reduces their ability to complex proteins (tannins becomes more polymerized, resulting in a lower number of free hydroxyls available for binding the proteins).

Polyethylene glycol (PEG) can be used to increase intake of diets rich in tannins by animals; because the former has a higher affinity for tannins than proteins. PEG can be sprayed on the forages or added in the diet but it is fairly expensive compared to other methods of removing tannin. They (PEG) when used can increase feed palatability and digestibility and result in higher animal productivity (Mlambo *et al*, 2001).

Low molecular weight phenolics can also decrease feed intake. They are in great proportion during the early stages of plant growth and are converted to oligomers and finally to polymers (tannins) when the plants mature. These low molecular weight phenolics are absorbed into the body and exhibit systemic effects such as alteration of physiological systems, increased energy requirements due to detoxification and subsequent growth rate reduction.

2.2.7.1 Effect of tannins on digestibility of feeds in animal species:

Several studies have shown that tannins decrease organic matter and fibre digestion. Also *invivo* studies show that protein digestibility is greatly reduced when tanninferous feeds are part of the diet. Reed (1995) reported negative digestion co-efficient for neutral detergent insoluble nitrogen (NDIN) and acid detergent lignin (ADL). Tagari *et al*, (1976) observed that the sheep fed sorghum silage having 18.7g tannins/kg had depressed digestion of crude fibre and less microbial activity in the rumen component compared with another sheep fed with maize silage containing 6.6g tannins/kg.

Chemical and biochemical nature of tannins may have effect on protein digestibility. Differences exist in the digestibility of protein of tree leaves with their total tannin content in consideration (Kumar and Singh, 1984). According to these authors these differences are as a result of chemical and biochemical nature of the tannin and their degree of polymerization.

Osakwe *et al* (1998) and Getachew *et al* (2000) have reported the depressive effect of tannin in browse on ammonia nitrogen concentration in *in vivo* digestion. When tannin containing browses were incubated alone in low nitrogen, the net production of ammonia nitrogen ranged from 3.2 to 21.8mh/l. But the addition of polyethylene glycol (PEG) a tannin binding agent dramatically increased the ammonia nitrogen level as well as the amount of short chain fatty acid (SCFA) (Getachew *et al*; 2000). However, Durand (1989) observed ammonia nitrogen concentration of 5 to 28mg/l as being optimum for ruminal cellulolytic bacteria.

Rumen ammonia enters the plasma urea pool after it has been absorbed into the blood and such is converted to urea by the liver. Endogenous loss from tissue also enter this pool. Excess plasma urea nitrogen is excreted in urine preventing toxicity in the animals. High values of plasma urea nitrogen indicate an inability of the animal to utilize nitrogen made available by digestion. As with rumen ammonia, plasma urea nitrogen was higher in animals fed diets of *Sesbania sesban* than in those fed diet of *Acacia brevispica*. Similar results were obtained when diet containing *Sesban* were compared with diets containing *Acacia seyal* and *Acacia nilotica* (Rittner, 1987).

In in vivo studies, protein digestibility is greatly reduced when tanninferous feeds are part of the diet. Plants high in Protanthocyanidins (PA_S) often have proteins linked tightly to the plant cell wall (Neutral Detergent Insoluble Nitrogen, NDIN) and lignin (Acid Detergent Lignin, ADL) components, and this may show negative digestion coefficients when ingested. After

ingestion, PAs may also form detergent insoluble tannin protein complexes with proteins they encounter. These two factors may cause the amount of NDIN and ADL excreted in the faeces to exceed the amount ingested. When dietary contents of tannins increased, feacal nitrogen excretion increased due to lower digestibility of nitrogen fractions and the formation of tannins-protein complexes. However, despite the decrease in apparent nitrogen digestibility, nitrogen retention does not always decrease with increasing tannin concentration in the diet. In many cases nitrogen retention increased as a result of decreased urinary excretion. The effects of tannins on protein digestibility of specific feeds can be estimated using Lucas's test (Van Soest, 1994).

If protein digestibility is not affected by tannins, proteins behave as uniform fraction, with a regression coefficient or time digestibility equal to or greater than 0.88, with a negative intercept (estimate of metabolic endogenous nitrogen, usually about 0.5% of dry matter intake or smaller) and with a low standard error. However, if protein digestibility is affected by tannins, the proteins will behave as a non-uniform fraction with a regression coefficient (that is true digestibility) smaller or lower than 0.88 and with a larger negative intercept and on higher standard error (Van Soest, 1994).

The efficiency of tannins in binding proteins and / or fibre is a function of the solubility of the tannin. If the ratio of soluble to insoluble tannins is high, then protein digestibility is affected more than fibre digestibility. But if the same ratio is low, fibre digestibility will be the most affected (Van Soest, 1994).

Tannin toxicity also affects rumen microorganisms like *Streptococcus bovis*, *Butyvibrio fibrosolvens*, *Fibrobacter succinogenes*, *Prevotella ruminicola* and *Ruminobacter amylophilis*. Tannin toxicity can result to enzyme inhibition and substrate deprivation, affect the membranes

and cause metal ion deprivation. Tannins also induce changes in the morphology of several species of ruminal bacteria. Hydrolizable tannins in particular are toxic to ruminants. Example ruminants and other species when fed with oak (*Quercus species*) and other tropical tree legumes like *Terminalia oblongata* and *Clidema hirta* experienced tannin toxicity because of the presence of hydrolysable tannins (HTS) in such species. Also HTS may be dangerous because microbial metabolism and gastric digestion convert them into absorbable low molecular weight metabolites; some of which are toxic. Hydrolyzable tannin poisoning can cause lesions in the animals, as in haemorrhagic gastroenteritis, necrosis of the liver, and kidney damage with proximal tuberal necrosis. Feeding sheep and cattle with oaks and other tree species with more than 20% HT resulted to high morbidity and mortality in the above species. Also protanthocyanidins (PA) toxicity can affect digestion of proteins and carbohydrates. They are not absorbed by the digestive tract, and may damage the mucosa of the gastrointestinal tract, thereby decreasing nutrient absorption and reducing the absorption of essential amino acids. The amino acids mostly affected are methionine and lysine. Decreased methionine availability could increase the toxicity of cyanogenic glycosides, because methionine is involved in the detoxification of cyanide via methylation to thiocyanate (Reed, 1995)

Micro organisms and some species of animals have defence mechanisms against tannins. Micro organisms defence mechanisms against tannins are; secretion of binding polymer, synthesis of tannin – resistant enzymes and biodegradation of tannins (some recently discovered bacteria are able to tolerate high levels of PA).

Also amongst animals, some are known to have better tolerance to tannins and can take in reasonable quantities of tannin with little or no adverse effect. Example, *Hoatzin* a ruminant – like- bird has the ability to eat a lot of tannin- rich leaves. While some insects can consume

leaves with high level of tannins. They have mechanisms that help them to adapt to tannins viz alkaline gut pH, presence of surfactants to decrease affinity between ingested tannins and protein and presence of peritrophic membranes that absorb tannins for such to be excreted in the faeces.

Also some tannin-consuming animals secrete a tannin-binding protein known as mucin in their saliva. The ability of salivary mucin to bind tannin is directly related to its pro-line content. Salivary proline-rich proteins (PRPs) have many advantages over dietary protein in inactivating tannins. The former can activates tannins more than dietary protein, thereby resulting in reduction in faecal loss of nitrogen; they also contain non specific nitrogen and non-essential amino-acids, that makes them more convenient for animals to exploit instead of using up valuable dietary protein. Differences exist amongst species in the amount of PRP they can produce to bind tannins in this order (from highest to lowest): Deer> Goat> Sheep and> Cattle (Robbins *et al*, 1987).

2.2.7.2 Positive effects of tannins:

Tannins in the feeds of monogastrics may generally have adverse effects on them; but in some ruminants tannins can cause or have beneficial effects. Condensed tannins even though having the disadvantages of interfering with intake and digestion of feeds at high levels are said to have beneficial effects at very low levels (Foo *et al*, 1996).

Acacia nilotica tannins have been used to treat cotton seed cake to prevent rumen degradation of proteins contained in the cotton seed cake. Tannin may complex proteins at the pH of the rumen (pH 6-7) to protect protein from microbial enzymes. These complexes are unstable at the pH of the abomasum and may make such protein available for digestion eventually. According to Tanner *et al* (1994) tannin in *Lotus pedunalatus* has been found to be

associated with an increased flux of amino acids through the abomasum. Tannins may also reduce nitrogen availability so much to slow rumen fermentation and this will increase the level of ammonia in ruminants. Increase in level of ammonia will consequently lead to low plasma urea nitrogen and this will reduce loss of nitrogen in urine. Browse plants have the ability to lower fermentation of nitrogen contained in them and this helps to improve the utilization of crop residues which also ferment slowly. It is also possible that some species of animals are able to synthesize tannin resistant enzymes and can degrade tannins biologically (Reed *et al*, 1990 and Reed, 1995). However, how the above occurs in species is yet to be understood.

The following are specific advantages of tannins in some species;

- In sheep and cattle higher retention of nitrogen has been observed when the level of tannins in forages is between low to moderate (2 to 6%). Here, the lower apparent and true digestibility of nitrogen was compensated for by reduced urinary loss of hydrogen.
- Moderate levels of tannins (less than 4%) in forage legumes can give beneficial responses in ruminants, leading to higher growth rates and milk yield. However, tannin levels should not exceed 6% of the diet even for ruminants otherwise growth rates and milk yield will be affected negatively (Hagerman and Klucher, 1986). The following are the suggested mechanisms behind the influence of tannin on protein utilization by ruminants-rumen escape, urea recycling and microbial efficiency.

In addition to the above benefits of tannins, some researchers have reported that some species of browse plants can be used for anthelmintic purposes. For example *Acacia mearnsii* (Wattle tannin) has been found useful in treating gastro intestinal nematodes) (GIN) in small ruminants.

According to Hassanpour *et al* (2011) Wattle tannin has an anthelmintic effect against gastro intestinal nematodes (GIN) of small ruminants depending on the dosage. Also forage species like Acacia species that are capable of reducing parasitic infection can be used solely or in conjunction with limited drugs to control parasitic worms. Forages with anthelmintics potentials have the following advantages – ability to reduce worm burden, fecundity of female nematodes, egg hatching ability and faecal egg counts in infected animals. They can also improve performance of ruminants and can serve as alternative anthelmintic agent in livestock when suitable doses are given to livestock (Hassanpour et *al.* 2011). Condensed tannins (CTs) are also useful in preventing bloat; they reduce the impact of worms and flies on ruminant performances. CTs may also help to fertilize lands for farming by decreasing the rate of proteolysis in rumen to cause a decrease in ammonia production. This will result in nitrogen contained in the diet to be excreted in the faeces rather than in urine. Such faecal nitrogen when incorporated in the soil structure will be of benefit to regions with poor soil structure; as well as reduce contamination of ground water by urinary nitrogen in temperate agricultural regions.

The mechanism by which tannins reduce infection of endo-parasites is still unknown. However, there is speculation that the beneficial properties could be due to tannins complex with dietary protein, which prevent rumen degradation thereby increasing duodenal protein flow once the complex dissociates in the acidic conditions of the abomasum; and this will increase the supply of protein to the host animal. This supply of additional protein to parasitized animals helps to expel the worm burden from the GIT more rapidly, as judged by the presence of nematode eggs in the faeces of such animals by raising the capacity of immune response (Martin *et al*; 1985). It was also speculated that CTs may have toxic effects against nematodes (Butter *et al*. 2000). Possible mechanisms of CTs for reducing the nematodes numbers include; improved

protein nutrition because less forage protein is degraded in the rumen, direct effects of CTs upon resident worms or an increased mucous production which reduce the ability of nematodes to persist in the abomasum and intestine, or a combination of all the above.

Dosages of Wattle tannins (WT), may be given orally as drench at a dose of between 1.3 and 1.6g WT/Kg body weight per day for three consecutive days respectively. The above will be effective for decreasing faecal egg count (FEC) and egg hatchability in naturally acquired nematodes infections in sheep (Max, 2010). Also, Sadaghian *et al* (2011) recommended drenching 1, 1.5 and 2gWT/kg body weight as one dose suspension. According to them, the above dosage significantly reduced FEC in acquired Moghani ewes aged 6-12 months. Max (2010) also reported that the presence of WT in culture media significantly reduced egg hatchability. In goats, the effect of WT on faecal egg count (FEC) and worm burdens was found to be negligible. Tannins could have effects on other important parasitological parameters such as female worm fecundity or reduction in hatchability of egg worm in faeces passed out after WT administration.

In conclusion, to avoid the problem of over-reliance on anthelmintic drugs for the treatment of worms with its attendant problem of development of multiple resistance by worm; condensed tannins extracts (CTE) are alternative means for reducing worm burden, fecundity of female nematode and egg hatchability (Marley *et al*; 2003; Nguyen *et al*, 2005; Hassanpour *et al*, 2011). This is a better and more practicable option particularly in the tropical and subtropical regions where marginal level of nutrition raises the consequences of worm infection with attendant rise in animal death from nematode infection. In addition, in the tropics and sub-tropical areas anthelmintic agents are becoming either unaffordable or their poor quality and or extensive multiple resistance makes such agents ineffective.

2.2.7.3 Effect of tannin on gas production:

Tannins are phenolic compounds commonly found in plants. They help plants to protect themselves from predation, they also perform the role of growth regulation when digested by herbivovous species. The two classes of tannins, hydrolysable and condensed tannins are located in the leaf, bud, seed, root and stem tissues of plants, they can have adverse or beneficial effects on species depending on their concentration and nature. Tannins when digested in high amounts may reduce the activity and the number of microbes in the rumen, and this will reduce ruminal biohydrogenation (Vasta *et al*, 2009). Tannins can also precipitate protein and hinder the absorption of nutrients. Infact, at very high level of intake, tannin can cause toxicity that may subsequently lead to death of animals (Bate- Smith and Swain, 1962).

Also the presence of tannin depresses the in vivo gas, short chain fatty acids (SCFA) and volatile fatty acid (VFA) production (Khazaal *et al* 1994). The above parameters could be used to determine the rate of digestion of a feed material (Gatechew *et al*, 2000). There could be decrease in rumen VFA, Microbial deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) production following increase in the concentration of tannic acid in the diet of animals (Sandanandan and Arora, 1979). The depression in the fermentation may be attributed to either direct interaction between tannins and bacteria cell wall (Jones et al; 1994), or the effect of tannin on microbial enzymes. The higher production of short chain fatty acids from straws in comparison with browse showed the low energy value of browses.

2.3 THE USE OF SWEET POTATO FORAGE IN LIVESTOCK PRODUCTION

2.3.1 Use of sweet potato in livestock feeding:

Sweet potato (*Ipomoea batata*) is a very important food crop. It is a tuberous rooted perennial that is cultivated for its – fleshy edible tubers. Flesh colours can be white, yellow, orange and purple; although orange-fleshed varieties are preferred because of their high vitamin A content (Kemper, 2009). They are grown by farmers both in the temperate regions and also in the tropics for human consumption and for the feeding of livestock. It has been used by different researchers for the purpose of maintenance, live weight gains of animals as well as a supplement. The foliage of sweet potato can be used as an alternative supplement to dried brewers grain (DBG) for feeding lactating cows. According to Etela *et al*. (2006) when used to replace dried brewers grains (DBG) in cows it resulted in low levels of milk yield, but was a cheaper alternative to dried brewers grain.

In many countries in the tropics, namely Nigeria, Rwanda, Kenya, Uganda etc, sweet potato has been used in the feeding of livestock including small ruminants – sheep and goats (Orodho 1999; Rashid *et al*; 2000; An *et al,* 2003; Olorunnisomo 2007). As a supplement, the vines of sweet potato was used to increase intake and rate of live weight gains in weaned goats (Karachi and Dzowela, 1990). Semenye and Hutchcroft (1992) found no significant differences in growth between kids weaned on sweet potato vines and kids that received all the milk from their dams. Lukuyu (2007) reported that from the findings of farmers in Rwanda, the vines of sweet potato have a potential for promoting increase in milk production in ruminants. Sweet potato vines provide sufficient crude protein and metabolizable energy to sustain goat meat and milk production in tropical countries, during scarce periods where standard feeds are lacking (Nambi *et al*, 2001, Katongole *et al*, 2008; Katongole *et al,* 2009). Still on the importance of

sweet potato vines, Aregheore and Perera (2004) recommended increased use of this feedstuff because they can provide cheap nitrogen and can also increase feed efficiency. Aregheore and Perera (2004) reported a higher animal performance (44 to 82g daily weight gain) when sweet potato vines were used to supplement a cotton seed cake and maize bran mixture at 1:4 ratio on a low quality grass *(Ischaemum aristatum var. indicum)*. The chemical composition of sweet potato vines and milk are comparable; while milk has a moisture content of 85% and digestibility of 86%, fresh vines of sweet potato has 80% and 72% respectively of moisture and digestibility. According to Semenye and Hutchcroft (1992), sweet potato vines met the requirements of the kids of dual purpose goats when fed 30g DM/kg of body weight per day. Osuji (1982), recommends the use of sweet potato vines in feeding livestock as it contains a relatively high crude protein and low crude fibre; 15 to 20%, and 12.5% respectively of dry matter.

2.3.2 Nutritional values of sweet potato forage:

Sweet potato foliage in fresh, dried or silage form has been described as a valuable material for livestock feeding. However, dried and ensiled sweet potato foliage has slightly lower lysine digestibility and overall nutritive value (An, 2004). Man (1994) reported that at 20 days of age sweet potato vines have low dry matter of 9.5% and high protein content of 23.6%.

Also Lam and Ledin (2004) reported that sweet potato vines contain the following nutrients: dry matter 11-12%, ash 7%, crude protein 22-23%; neutral detergent fibre (NDF) 35-36% and acid detergent fibre (ADF) 26-27%. According to Semenye and Hutchcroft (1992) the following is the nutritional value of sweet potato vines: crude protein 16% moisture 80% and *in vitro* dry matter digestibility 74% (DM) . Karachi (1982) and Orodho (1990) gave the following as the nutritional values of different parts of sweet potato- vines 17.5% crude protein, leaf 30% crude protein other parts 10% crude protein; fibre contents of leaf and petiole was relatively low

(ADF) 22% and 28% respectively. Moisture contents of leaf and petiole was high at 80-90% respectively.

2.3.3 Advantages of sweet potato over other root crops:

Sweet potato has a lot of advantages over other crop plants. It is widely cultivated for food and for livestock feeding in more than 100 countries of the world. The area under cultivation was put at 8.5million hectares in 2009; while the world wide tuber yield was 12648kg/ha (FAO, 2010). According to FAO (2010) report, Nigeria is amongst the largest producers of sweet potato in Sub-Saharan Africa. They are widely grown in different parts of Nigeria mainly for food but also for feeding livestock. It is widely cultivated because of the following advantages; it requires very little care when planted; it can yield more carbohydrate per hectare in 4 months, whereas yam can take 7-8 months or more to mature; they also require very little or no need for weed control after establishment. Specifically, the vines of sweet potato are cultivated because of the following advantages: high yield ability, high palatability, high crude protein content and high moisture content when fresh.

2.3.4 Ways of processing sweet potato and benefits of processing:

Sweet potato forage can be processed into supplement in dried form or as silage. Vines are cut for drying for a period of 2-3 weeks depending on the weather condition and the degree and duration of sunshine. Such cut vines may be hung on trees, fences, walls or other structures that are strong and high enough to support the vines through the period of drying, to avoid dissipation of energy and the difficulty involved in manually cutting dried forage/ vines. They may be manually chopped to 25cm using machetes when still fresh, to quicken the process of drying as well as enhance feeding after drying.

Sweet potato vines can also be ensiled or preserved as green fodder in a silo, or on a smaller scale in batches using air-tight plastic or nylon bags. This allows using one bag of preserved forage at a time, so that all the stored silage is not exposed to the air.

According to Tinh (2000) processing sweet potato into silage has the following advantages:

- Gives farmers the option of harvesting forage at once, instead of the traditional piece-meal harvesting. This would allow the land to be cultivated for three crops instead of two crops a year.
- Avoids discarding or wastages of vines, which can be preserved for future use. Large quantities of vines will be wasted where farmers do not have the know-how required for storing or conserving them, particularly at the peak of harvest.
- Processing of vines also leads to improvement in their nutritional values.
- Long storage life allows farmers to feed live stock a regular diet, instead of a large volume at harvest time, only to run out of feeds until another harvest season.

Sweet potato can be processed and used in different forms for feeding livestock (Heuz´e *et al*, 2012). Generally, processed and stored sweet potato vines are cheap and very useful in feeding species during the off-season when vines and other feeds are expensive. Preserving sweet potato forage should be encouraged because the major constraints to using sweet potato vines in feeding livestock (high labour for chopping vines into small pieces and difficulty in storing them) can be overcome by turning the vines into silage (Tinh, 2000).

If vines be the main objectives of cultivating sweet potato, they can be planted on flat fields at a spacing of 30-40cm between plants and 40-50cm between rows. Planting too close limits the efficiency of photosynthesis. Depending on the rainfall level, vines can be harvested

30-45 days after planting and every 15-25 days after. The optimal way to cut multiple vines is to cut 1-2cm of the longest branches of each plant leaving about 10cm for re-sprouting. Good quality sweet potato vines silage will be brownish green in colour. It will have pleasant aroma/ fruit smell. Animals cherish sweet potato vine silage and it can be given free- choice to animals.

2.3.5 Necessary guides for effective use of sweet potato forage:

Even though sweet potato is useful as a forage for livestock, there is need to apply some caution in its use because it has been implicated as responsible for some body disorders in cattle when wrongly used. For example, the metabolites ipomea marone and ipomeas maranol have been isolated from mouldy tubers and were found to be toxic to the liver and other organs of the body. Ipomea maranol can also cause lung oedema.

Also the nutritional value of sweet potato is low compared to that of yam and Irish potato. According to Horton (1987), the protein content of Irish potato is about 2%, a level similar to that of yam, and nearly double that of sweet potato. However, in terms of food production per hectare, per day, sweet potato has advantage over Irish potato.

In this study, efforts were made to ensure that the parts of sweet potato to be used (the vines and the leaves) are properly processed and stored to guarantee their safety for the use of the animals. Such vines and leaves (forage) were well- cured and preserved before giving them to the animal.

2.4 MICROBIAL DIGESTION IN RUMINANTS

A major feed resource for ruminants is roughage, and this is made up of polysaccharides viz hemicelluloses, cellulose, lignin and pectin (in their descending order of digestion). Roughages provide energy to ruminants primarily. Forage materials are made up of plant nutrients and other secondary plant components like polyphenols, saponins and silica (Wang *et*

al., 2000). Cellulose is the most abundant polysaccharide in the cell wall, accounting for 20 to 30 percent of the dry weight of most plant cell walls (Wang and McAllister, 2002).

Roughages are digested for use of host animal by the activity of micro organisms found in the rumen. The rumen has a great number of obligatory anaerobic bacteria, fungi and protozoa that together act on the roughages to ferment them for the use of ruminants. Bacteria and fungi are responsible for approximately 80% (percent) of the degradative activity in ruminants and protozoa 20 percent (Wang and Allister, 2002). Effectiveness of rumen micro organisms can be enhanced by the chemical and physical nature of the roughage, feeding protein along with roughage and by processing the roughages into better usable forms. Use of roughages can also be enhanced by introducing them gradually to animals to allow them build up or develop relevant microbes for their digestion. There is need to check the population of protozoa in the rumen because they may become dangerous predator to other useful microbes if they out number such other useful microbes (William and Coleman, 1991).

Fibrolytic bacteria are generally considered the primary organisms behind the degradation of plant cell wall in the rumen (Findlay, 1998). Compared to bacteria, the role of fungi is not clearly understood. But the fungi in the rumen are responsible for the production of many enzymes that help the ruminants to degrade a wide range of substrates. They also have a special ability to penetrate the cuticle at the plant surface and cell walls of even lignified tissues (Akin, 1989). Ruminal protozoa are useful in the digestion of plant cell wall polymers and their absence in the rumen may have negative effect on the degree/ level of fibre digestion (William and Coleman, 1991).

Microbial enzymes in the rumen need to work harmoniously or jointly for structural carbohydrates in roughages to be utilized by animals. The population of microbes and fibrolytic

enzymes produced by individual micro organisms work together to make the digestion of roughages possible in ruminant (Wang and McAllister 2002). If hydrolysis of roughage must take place in the rumen, activities of enzymes in the rumen must be co-ordinated with that of feed substrates.

The rumen is made up of a heterogeneous mixture of liquid and solids. Polysaccharide degrading enzymes secreted into fraction are at the risk of inactivation by proteolysis or of being washed out of the rumen before they get into contact with their substrate. According to Brock *et al.* (1982) hemicelluloses and cellulose activities are notably higher in the particulate fraction of ruminant contents than in the fluid. Microbes prolong their residence or occupation of the rumen by attaching themselves to feed particles, thereby bringing their enzymes in close contact with feed substrates.

The concept of feed-by pass, where dietary protein and fat are made to pass through the rumen intact and also post ruminal digestion of carbohydrates may cause more problems to ruminants than it solves (Ørskov, 1994). Also the capacity of ruminants for intestinal starch digestion and glucose absorption is low and utilization of such exogenous glucose is limited.

2.4.1 Limitations of cell wall digestion by rumen micro organisms:

Based on the diets they prefer, ruminants can be classified into distinct feeding types viz concentrate selectors, grass / roughage eaters and intermediate types. The relative size of various digestive system organs differs amongst ruminants based on the way they feed, and this creates differences in feeding adaptations. Goats are classified as intermediate types of ruminants, they prefer forbs and browse such as woody, shrubby type of plants. They have adaptations of those that can consume concentrate and grass/ roughage eaters. Goats have a fair, but limited capacity to digest cellulose in cell walls.

The reticulo-rumen is home to a population of micro-organisms like bacteria, protozoa and fungi. These microbes ferment and break down plant cell walls into their carbohydrate fractions to produce volatile fatty acid (VFAs) namely acetate for fat synthesis, propionate for glucose synthesis and butyrate from carbohydrates. Ruminants later use VFAs for energy production.

Ruminants are not able to completely digest fibrous feedstuffs like ingested cell wall of polysaccharides. This incomplete digestion of polysaccharides is caused by both biochemical and physical factors present in the ingested substrate; and by limits of retention time on the ingested substrate inside the rumen. Also some components of feeds like phenolics, silica, saponins and lignin have negative effects on cellulytic activity (Bae *et al*; 1997). According to Wang and McAllister (2002), the major obstacle to cell wall degradation in the rumen is likely to be the cross linkages among cellulose, hemicelluloses, lignin and other compounds that hinder the access of enzymes to the substrate inside the rumen. In addition to the above limitation, concentration of cellulose, hemicellulose, lignin and other parts of the cell wall of plants on the surface of feed particles may prevent microbial attachment and subsequently their effectiveness in digesting such feed material.

Another limitation to the complete digestion of plant cell wall materials is the limited retention time of such material in the rumen. The larger the particle size of feeds the longer the feed particles are likely to be retained in the rumen and the greater the degree of degradation. Retention time, therefore, affects the degree/level of digestion of polysaccharides but not the rate of digestion.

Apart from the above limiting factors to effective use of plant cell wall by ruminants; the outer layer of epiticuticular waxes, cuticle and pectin of grasses, legumes and cereal grains

together form a strong barrier to the penetration of microbes into such substrates inside the rumen. Akin (1989), observed that the resistance of plant cuticle to microbial digestive enzymes can be reduced by mastication of forage, pre-treatment of cereal grains in order to minimize their deleterious effect on digestion.

2.4.2 Evaluation of forage digestion by gas production:

Inside the rumen forage is exposed to a great population of microbes that initiates the fermentation and digestion of plant cell walls into carbohydrates and sugars. Rumen microbes use the carbohydrates with ammonia and amino acids in feeds to grow. Microbes ferment sugars to produce volatile fatty acid – acetate, propionate and butyrate; other gases produced are methane, hydrogen sulfide, carbon (iv) oxide (Bergman, 1990).

Proper feeding of ruminants requires that the quantity and quality of forage offered to them and the proportion of this consumed by them be correctly estimated (Valentine *et al.*, 1999). Improved performance of ruminants will be achieved when the nutritive value and intake are used to estimate what should be offered to them as supplementary feeds.

One method of determining the digestibility of forages and their nutritive value is the in vitro method or techniques (Tilley and Terry 1963; Menke *et al* 1979 ; Aufrere, 1982). Gas production has been found to be an accurate way of predicting the performance of ruminants on certain species of forage. According to Khazaal *et al*; (1993^{b}) while the gas production technique was found to be slightly inferior to the nylon bag technique in determining the nutritive value of hays it was suggested to be more efficient than the latter for determining the nutritive value of feeds containing anti-nutritional factors. The gas production techniques in combination with polyvinypolyueriolidone (PVP) was reported to have a good potential for providing better insight into the effects of phenol related anti-nutritive factors in biological

systems (Khazaal *et al*., 1994). The gas technique differs from other in vitro techniques by measuring evolution of gas as a result of fermentation.

Gas production of different feed-stuffs depends on the methodology used, the type of substrate, the type of animal used, the number of measurements and precision of description of the degradation curve; and lastly the mathematical model employed (Valentine *et al*., 1999). Bogoro *et al*. (1999) measured gas production of sorghum stover at different periods – 3, 6, 12, 24, 48, 72 and 96 hours, and got the following results – 3.16, 5.50, 11.00, 19.40, 28.77, 33.43 and 37.20mls respectively. With untreated Ragi Straw, 4 percent of urea treated Ragi straw, 6 percent urea treated Ragi straw and concentrated mixture; gas production after 24 hours were 39.15, 37.22, 28.43 and 36.99ml, respectively (Ramachandra and Krishnamoorthy, 2000). According to Khazaal *et al.* (1994), gas production from 8 browse plants studied for 24 and 48 hours varied. Gas produced ranged from 14.8 to 35.1ml in 24hours and 26.60 to 38.70mls in 48 hours. The above authors (Khazaal *et al*., 1994) observed that a strong relationship ($R^2 = 0.84 : P < 0.01$) exist between the increase in percentage (%) in gas produced and the change in total VFAs.

Beuvink (1993), described the curve of gas production on dry matter disappearance as a sigmoid curve with 3 phases viz: slow phase, involving hydration, microbial attachment and colonization. The second phase (exponential) represents enzyme degradation and the third phase (Asymptotic phase) when gas production rate decreases and falls to zero. Other authors, Valentine *et al*., (1999), did not find such curve in either the gas produced or in dry matter disappearance; instead they reported linear and exponential functions. Also Blummel and Ørskov (1993) observed a correlation between dry matter degradability and gas production at 48 hours,

but they did not obtain a relationship between the rate of dry matter degradation and gas production.

2.5 VOLATILE FATTY ACIDS

Volatile fatty acids, also known as short-chain fatty acids, are produced in the GIT by microbial fermentation of carbohydrates and endogenous substrates such as mucus. According to Bergman (1990) they can be of great advantage to the animal since no digestive enzyme exists for breaking down cellulose or other complex carbohydrates. VFAs are produced by both herbivorous animals and other species including man at different sections of their gastrointestinal tract (GIT). The greatest quantity of VFA is produced in the rumen of ruminants and in the lower digestive tract of man and other species. The major VFA in either the rumen or the large intestine are acetate, propionate and butyric acids. They are produced in a ratio varying from approximately 75:15:10 to 40:40:20 (Bergman, 1990).

Volatile fatty acids (VFAs) are the main source of energy to ruminants (Bergman 1990). After absorption at their site of production, they are metabolized by the ruminal or large intestinal epithelium before reaching the portal blood and are used for the following purposes:

Most of the butyrate (butyric acid) is converted to ketone bodies of Co_2 by the epithelial cells; while unused ones are removed by the liver. Propionate (Propionic acid) is removed by the liver, but is largely converted to glucose. Acetate is used principally by peripheral tissues, especially fat and muscle.

Volatile fatty acids (VFAs) offer considerable energy to herbivourous species; also pigs and man can produce significant quantity of VFA. VFAs contribute approximately 70% to the caloric requirements of ruminants (sheep, goats and cattle), up to 10% for man and approximately 20-30% for other carnivorous species (Bergman, 1990).

In addition to energy production, VFA may indirectly influence cholesterol synthesis and even help regulate insulin glucagon secretion. The production and absorption of VFA has a very significant effect on epithelial cell growth, blood flow and the normal secretory and absorptive functions of the large intestine, caecum and rumen. Also the absorption of VFA and sodium seem to be interdependent, and release of bicarbonate usually occurs during VFA absorption.

Increasing the dietary fibre of species may be recommended, because this will lead to increase in the production of VFA; and this will increase the contribution of VFA to the energy supply to the body. The proportion of acetic acid usually increase with increases cellulosic roughages in the diet while grain or starch usually ferment to yield a higher proportion of propionic acid. Ørskov, (1994) observed that feeding whole rather than rolled barley, wheat, oats and maize had a very large influence on the type of fermentation. Therefore chemical composition of feedstuffs alone may not be enough as a basis for determining the type of fermentation to expect. According to Ørskov (1994) the type of fermentation depends on rumen environment, especially the pH and the degradation rate of substrate. About 80% of the volatile fatty acids produced in the rumen are absorbed through its wall, the surface area of which is greatly enlarged by numerous papillae. These papillae grow and regress in response to changes in food consumption and VFA concentration. Other remaining VFA is absorbed in the omasum and the abomasum (true stomach).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENT 1: COLLECTION, PROCESSING AND EVALUATION OF *ACACIA NILOTICA* PODS AND SWEET POTATO FORAGE

3.1.1 Experimental Site:

The study was conducted at the Small Ruminant Unit of Department of Animal Science, Ahmadu Bello University, Zaria, located within the Northern Guinea Savanna Zone of Nigeria, latitude 11^0 33'N and longitude 7^0 42'E and at a height of about 22,100 m. above sea level. The climate is relatively dry, with a mean annual rainfall of 1102 to 1904mm, occurring between the months of April and September. The mean temperature fluctuates from 31^0 C ($88\ ^0$F) maximum in dry season to 18^0 C (65^0F) minimum in wet season (Google Earth, 2012).

3.1.1.1 *Acacia nilotica* (L.) Del Pods:

Dried *Acacia nilotica* pods used for this study were bought from farmers in Kano State. They were packed in 50 kg jute bags and transported to the Department of Animal Science experimental farm, of Ahmadu Bello University, Zaria for processing and storage. They were processed in 5 different ways:

a. Sun-dried for seven days, without milling (T_1)
b. Crushed, using heavy stick inside the jute bag after sun-drying for seven days (T_2)
c. Soaked, dried for seven days and milled (T_3)
d. Sun-dried for seven days, and milled (T_4)
e. Sun-dried for seven days, and milled with 1.25kg of charcoal for each 12.5kg of feed (T_5)

The *Acacia nilotica* pods used in treatment 3 were processed by soaking the pods inside water (in big rubber containers) for seven days and the water changed daily. The soaked Acacia were dried and milled. The above treated or processed Acacia pods were used to compound the

experimental diets with other feed ingredients viz : maize offal, cotton seed cake, *A.nilotica* pods, bone meal and salt as shown in Table 3.1 below :

Table 3.1: Composition of Experimental Diets used for the 1st Feeding Trial

Ingredients (Kg)	Sun Dried	Crushed	Soaked and Milled	Milled	Milled with Charcoal
Maize Offal	72	72	72	72	72
A. nilotica pods	12.5	12.5	12.5	12.5	12.5
Cotton seed cake	12.5	12.5	12.5	12.5	12.5
Bone meal	2.5	2.5	2.5	2.5	2.5
Salt	0.5	0.5	0.5	0.5	0.5
Total	**100**	**100**	**100**	**100**	**100**

3.1.2 Sweet potato forage:

Dried sweet potato forage (leaves and vines) used for the experiments were purchased mainly from local farmers at Dumbi Village along Kaduna express way. However, during the off-season, supplies came from other local farmers within villages in Zaria. One hundred and fifty (150) bags of dried sweet potato forage were transported from the different collection points and were stored in well ventilated rooms in Animal Science Experimental Farm, until the commencement of the study.

3.2 GROWTH STUDY:

3.2.1 Proximate and Chemical Analyses of Feeds:

Representative samples of the differently processed *Acacia nilotica* pods (T_{1-5}) and sweet potato forage were collected and chemically analyzed to determine their dry matter, crude protein, crude fibre, ether extract and ash contents, according to AOAC (2000). Cellulose,

hemicelluloses, acid detergent fibre and neutral detergent fibres were determined by the method of Van Soest and Robertson (1988). Flame spectrophotometer was used to determine the content of Calcium, Sodium, Iron, Zinc and Manganese in *Acacia nilotica* pod according to the method of Kennedy (1984). The presence of anti-nutritional factors viz: phytate, soponins, oxalates, tannin and cyanide in the feeding stuffs (*acacia nilotica* pods and sweet potato forage) was done chemically using the methods of Oke (1969) and Reddy *et al*., (1982). Also chemical analysis of the mixtures of *Acacia nilotica* pods and other feed ingredients (T_{1-5}) was done according to AOAC (2000) method. Samples of dried sweet potato forage were analyzed for its proximate contents using the procedure of AOAC (2000).

3.2.1.1 Feeding Trial:

The objective of this study was to evaluate the effect of feeding differently processed *Acacia nilotica* pods with other feed ingredient and sweet potato forage on the performance of Red Sokoto goats (Expt. I). This will serve as a basis for choosing the best out of the 5 processing methods used in this study. The products of the chosen method of processing Acacia pods will be used at different levels as replacement for CSC in practical diets (Expt. II).

Animals, feeds and feeding:

Twenty five male Red Sokoto goats of average age of 10 months and weighing averagely 10.2kg ± 0.4 Kg body weight were purchased from local markets in Zaria and Maigana. The animals were dewormed with anthelmintics (Albendazole®) to control endoparasite at 3ml/10kg body weight; and repeated after 2 weeks. Ivomectin (Ivomec®) was given at 0.5ml/25kg body weight subcutaneously against ecto-parasites. The animals were also given oxytetracycline (Tridox®) L/A antibiotics at 1.0ml/10kg body weight intramuscularly

against bacterial infections, one week before commencement of experiment; and dosage repeated after 3 days.

The animals were blocked according to their weights and assigned to treatments 1-5; (five animals per treatment) in a Completely Randomized Block Design (CRBD) experiment. The animals were individually offered the experimental diets and sweet potato forage. Each animal received a total of 3% of its body weight as daily allowance out of which, 40% and 60% came from the experimental diets and sweet potato forage, respectively. The experimental diets were given at 08.00 hours, while the sweet potato forage was offered 3 hours later daily. This was done deliberately to encourage maximum intake of the experimental diets. The left-over for each animal was measured the following day before the day's feeding. The feeding trial lasted for 90 days and records of feed intake, left-over's and body weight were taken.

The animals were weighed weekly using a hanging scale (Salter suspended weigher, model 235). The experimental diets and the sweet potato forage were adjusted weekly to 3% of their body weight. Quantities of feeds offered and left-overs were weighed daily to determine feed intake. Fresh clean drinking water was offered daily to the animals free-choice.

3.3 BLOOD COLLECTION

Blood was sampled from the jugular vein of the selected animals, three per treatment with a hypodermic needle into vacutainer tubes (2 for each animal, the tubes for blood plasma contained anti-coagulants (EDTA) while the tubes for blood serum were plain) on days 1, 45 and 90 of this study at zero hour (before feeding), and at three, six, nine and twelve hours after feeding respectively. Blood samples were centrifuged immediately after collection and plasma decanted into tubes and stored at -4^0C. Plasma urea nitrogen was determined using Archer and Robb (1925) method.

Design and Statistical Analysis:

The animals were blocked to balance for weight differences in a Completely Randomized Block Design (CRBD) and assigned to individual pens, 5 animals per treatment. Data generated from this study were analyzed using the General Linear Model (GLM), Analysis of Variance Procedure of Statistical Analytical System (SAS, 2005). Treatment means that were significant were separated using Duncan's Multiple Range Test (DMRT).

3.4 DIGESTIBILITY TRIAL AND NITROGEN BALANCE

The aim of this trial was to evaluate the apparent digestibility of nutrients and nitrogen balance by Red Sokoto goats fed diets containing differently processed Acacia pods.

Animals:

Four (4) animals were randomly selected from each treatment at the conclusion of the growth study. They were put in individual metabolism crates and fed their respective rations as was the case during the feeding trial. Faecal and urine samples were collected for seven days after 14 days adjustment period. Prior to the day of sample collection 10ml of 10% H_2SO_4 was put into a graduated plastic vessel to keep the nitrogen in the urine intact. Faeces were also collected under a wire mesh (netting) suspended under the digestibility crates.

Feed intake was determined by finding the difference between the quantity of feeds offered and the amount of feed refused. Samples of feeds, faeces and urine were taken daily for the seven days collection period. The daily faecal output was weighed, the daily urine voided was measured and samples taken from their total to the laboratory for analysis. A 5% aliquot of total urine output per day was taken to the refrigerator daily and stored at (-4^0C). Measured samples of faeces from each animal was bagged in white polythene bags and stored in the

freezer. Urine and faecal samples of the animals used for this study were bulked, mixed thoroughly and sub-sampled for proximate analysis.

Proximate and Chemical Analyses:

Samples of feed offered and faecal output were analyzed for dry matter, crude protein, crude fibre, ether extract, ash contents (AOAC, 1985), acid detergents fibre, neutral detergents fibre and hemicelluloses contents (Van Soest and Robertson, 1988). Urine samples were analyzed for nitrogen content.

Statistical Analysis:

Data generated from this study were analyzed using the General Linear Model (GLM) Analyses of Variance Procedure of Statistical Analytical System (SAS, 2005). Treatment means that were significant were separated using Duncan's Multiple Range Test (DMRT).

3.5 EXPERIMENT II: FEEDING TRIALS WITH SUN-DRIED *ACACIA NILOTICA* PODS

3.5.1 Experimental Site:

The study was carried out in the Experimental Unit of the Small Ruminant Research Programme of the National Animal Production Research Institute, Ahmadu Bello University, Shika Zaria. Shika is located in the Northern Guinea Savanna on latitude 11^0 12'N and longitude 7^0 33'E, altitude of 610m above sea level. Annual rainfall is about 1100 to1200mm while mean temperature is about 24.4^0C (14.5 – 39.3^0C) with the lowest temperature occurring during early dry season (November – January). Higher temperatures are experienced during the late dry season – February to April (Google Earth, 2012).

3.5.2 Growth study:

3.5.2.1 Proximate and Chemical Analyses of Feeds:

Results of Experiment I (Growth Study) showed that sun-dried *Acacia nilotica* pods (T_1) gave best results ; in terms of body weight of animals and labour/cost required in processing. Therefore, Experimental diets were formulated with sun-dried *Acacia nilotica* pods to replace cotton seed cake at 0, 25, 50, 75 and 100%. Samples of these diets were collected and chemically analyzed to determine their dry matter, crude protein, crude fibre, ether extract and ash contents using AOAC (2000). Cellulose, hemicelluloses, acid detergent fibre and neutral detergent fibres were determined by the method of Van Soest and Robertson (1988).

3.5.2.2 Feeding Trial:

The objective of this study was to evaluate the best level of replacing cotton seed cake with sun-dried *Acacia nilotica* pods in the diet of Red Sokoto goats.

Animals, Feed and Feeding:

Twenty five male Red Sokoto goats of average age of 10 months were bought from Dogorawa, Maigana and Makarfi goat markets, in Kaduna State. Their average body weight at the commencement of experiment was 10.3kg ± 0.1Kg. The animals were de-wormed with anthelmintics (Albendazole®), to control endo-parasites at 3ml/10kg body weight and was repeated after two weeks. Ivomectin (Ivomec®) was given at 0.5ml/25kg body weight subcutaneously against ecto-parasites. The animals were also given oxytetracycline (Tridox®) L/A antibiotics at 1.0ml/10kg body weight intramuscularly against bacterial infections, one week before commencement of experiment and repeated after 3 days.

The animals were individually penned and offered the Experimental diets made up of *Acacia nilotica* pods with other feed ingredients: maize offal, cotton seed cake, bone meal and

salt, and sweet potato forage as basal diet according to their treatments (Table 3.2). Each animal received a total of 4% of their body weight as daily feed allowance. Out of this total, 40% and 60% were provided by Experimental diets and sweet potato forage respectively. The Experimental diets were given at 08.00 hours, while the sweet potato forage was given 3 hours later. This was intentional to encourage maximum intake of the Experimental diets. The left-overs for each animal were measured the following day before the days feeding. The feeding trial lasted for 90 days and records of feed intake, left-overs and body weights were taken.

Table 3.2: Composition of Experimental Diets containing varied levels of Sun-dried *Acacia nilotica* Pods

	Level of replacement of CSC with Acacia (%)				
Ingredients (Kg)	**0**	**25**	**50**	**75**	**100**
Maize Offal	60	60	60	60	60
Acacia nilotica	0	9.5	19	28.5	38
Cotton seed cake	38	28.5	19	9.5	0
Bone meal	1.5	1.5	1.5	1.5	1.5
Salt	0.5	0.5	0.5	0.5	0.5
Total	**100**	**100**	**100**	**100**	**100**

The animals were weighed after every two weeks, using a hanging scale (Salter suspended weigher, model 235). The Experimental diets and the sweet potato forage ration was adjusted after every two weeks at 4% of their body weight and to reflect the levels of cotton seed cake replacement – 0, 25, 50, 75, 100% (T_{1-5}). Fresh clean drinking water was offered daily to the animal's free-choice.

3.6 BLOOD METABOLITES

3.6.1 Procedure for blood collection:

Blood was sampled from the jugular vein of the selected 3 animals per treatment with a hypodermic needle into vacutainer tubes (2 tubes for each animal ,the tubes for blood plasma contained anti-coagulant (EDTA), while the tubes for blood serum were plain) at different intervals during the experiment – beginning, middle and end of experiment (1, 45 and 90 days). On the day of bleeding, animals were bled at five different times – before feeding, three, six, nine and twelve hours after feeding respectively. Blood samples were centrifuged immediately after collection and plasma decanted into tubes and stored at -4^0C. Plasma urea nitrogen was determined using Archer and Robb (1925) method.

Design and Statistical Analysis:

Twenty five Red sokoto goats (bucks) were blocked to balance for weight differences in a Completely Randomized Block Design (CRBD) experiment. Data generated from this study were analyzed using the General Linear Model (GLM) Analysis of Variance Procedure of Statistical Analytical System (SAS, 2005). Treatment means that were significant were separated using Duncan's Multiple Range Test (DMRT).

3.7 DIGESTIBILITY TRIAL AND NITROGEN BALANCE

The aim of this study was to evaluate the apparent nutrient digestibility and nitrogen balance of the different diets fed during the growth study by goats fed diets containing different levels of sun-dried Acacia pod as replacement for CSC.

Animals:

Four (4) animals were randomly selected from each treatment at the conclusion of the growth study. They were put in individual metabolism crates and fed their respective rations as was the case during the feeding trial. Faecal and urinal samples were collected for

seven (7) days after the adjustment period of 14 days. Prior to the day of sample collection 10ml of 10% H_2SO_4 was put into a graduated plastic vessel to keep the nitrogen in the urine intact. Faeces were also collected under a wire mesh (netting) suspended under the digestibility crates.

Feed intake was determined by finding the difference between the quantity of feeds offered and the amount of feed refused. The daily faecal output was weighed for each animal, the daily urine for each animal was also measured during the seven days collection period for laboratory analysis. A 5% aliquot of total urine output per day was stored in the refrigerator daily at -4^0C. Measured samples of faeces from each animal was bagged in white polythene bags and stored at -4^0C in the freezer. Urine and faecal samples of the animals used for this study were separately bulked, mixed thoroughly and sub-sampled for proximate analysis.

Proximate and Chemical Analyses:

Samples of feed offered and faecal output were analyzed for dry matter, crude protein, crude fibre, ether extract, ash contents according to (AOAC, 1985) method, acid detergents fibre, neutral detergents fibre and hemicelluloses contents according to (Van Soest and Robertson, 1988) method. Urine samples were analyzed for nitrogen content according to Archer and Robb (1925) method.

Statistical Analysis:

Data generated from this study were analyzed using the General Linear Model (GLM), Analysis of Variance Procedure of Statistical Analytical system (SAS, 2005). Treatment means that were significant were separated using Duncan's Multiple Range Test (DMRT).

CHAPTER FOUR

4.0 RESULTS

4.1 COLLECTION, PROCESSING AND EVALUATION OF *ACACIA NILOTICA* PODS AND SWEET POTATO FORAGE

4.1.1 Proximate and Chemical Composition of Experimental Diets:

The proximate and chemical analysis of the differently processed dried *Acacia nilotica* pods and dried sweet potato forage are presented in Table 4.1. The proximate analysis of the dried *Acacia nilotica* pods and dried sweet potato forage showed that soaked and milled Acacia pods (T_3) had the highest crude protein value (15.06%) , while Acacia milled with charcoal had the least crude protein (10.13%). Dried sweet potato forage has the highest crude fibre content (36.52%), while the least crude fibre was recorded in milled Acacia pods (22.73%).

The highest dry matter (DM) content was found in milled Acacia with charcoal (T_5) 98.19%, while the least DM (96.13%) was found in sun-dried Acacia pods. The highest value of ether extract (7.17%) was in crushed Acacia, while the least value of ether extract was in milled Acacia (3.34%). Differently processed Acacia pods and sun-dried sweet potato forage contained 23.82%, 26.89%, 31.06%, 22.73%, 31.18% and 36.52% crude fibre respectively.

Table 4.1: Chemical Composition of *Acacia nilotica* Pods Processed in Different Ways and Sweet Potato Forage

Parameters (%)	**Processing Methods of *A.nilotica***					
	Sun-Dried	**Crushed**	**Soaked and Milled**	**Milled**	**Milled with Charcoal**	**Dried Sweet Potato Forage**
Dry Matter (DM)	96.13	96.47	97.52	97.21	98.19	97.13
Ash	5.14	4.57	4.12	4.35	4.77	6.59
Crude Protein	12.69	12.13	15.06	13.25	10.13	9.25
Crude Fibre	23.82	26.89	31.06	22.73	31.18	36.52
Ether Extract	5.2	7.17	7.3	3.34	5.46	3.84
NDF	28.15	31.33	41.38	36.62	28.62	34.62
ADF	25.34	29.00	35.87	27.16	23.88	32.18
HC	2.81	2.33	5.51	9.46	4.74	2.44

NDF = neutral detergent fibre, ADF = acid detergent fibre, HC = hemicellulose, ME = metabolizable energy and SP = sweet potato forage.

Table 4.2 shows the mineral contents of the dried Acacia pods. The dried *Acacia nilotica* pods contained the following minerals: sodium 0.05%, potassium 1.00%, calcium 4.00% (mg/kg), iron 0.03%, copper 0.00%, zinc 0.01% and magnesium 0.14%.

Table 4.3 shows the anti-nutritional factors (ANF) contained in sweet potato forage and the differently processed *Acacia nilotica* pods. Sun-dried Acacia pods (T_1) had the highest value of phytate (0.42mg), crushed Acacia pods (T_2), soaked Acacia pods (T_3) and Acacia milled with charcoal (T_5) each had 0.36mg of phytate; while milled Acacia pods (T_4) had the least value of phytate 0.30mg. Sun-dried Acacia pods (T_1) also had the highest value of saponin (0.70mg), while the least value of saponin was found in milled Acacia (T_4) and Acacia milled with charcoal (T_5). The highest value of oxalate (3.96mg) was found in Acacia milled with charcoal (T_5) and the least value of oxalate (2.64mg) was found in sun-dried Acacia pods (T_1) and milled Acacia pods (T_4). The highest value of tannin (1.30mg) was found in crushed Acacia pods (T_2), followed by sun-dried Acacia pods (T_1) with 1.20mg. The least content of tannin was found in Acacia milled with charcoal (T_5). The highest value of cyanide (0.43mg) was found in milled Acacia pods (T_4), followed by crushed Acacia pods (T_2) with 0.32mg of cyanide. The value of cyanide in treatments 1, 3 and 5 was 0.22mg respectively. The basal diet, dried sweet potato contained the following anti-nutritional factors – phytate (0.42mg), saponin (0.42mg), oxalate (2.98mg), tannin (0.90mg) and cyanide (0.32mg).

Table 4.2: Mineral Contents of Dried *Acacia nilotica* Pods

Mineral	Value
Na	0.05 %
Ca	4.00 (mg/kg)
Fe	0.03%
Cu	0.00%
Zn	0.01%
Mg	0.14%
K	1.00%

Table 4.3: Anti-Nutritional Factors (ANFs) in the Differently Processed *Acacia nilotica* Pods, and dried Sweet Potato Forage

Parameters (Mg)	Processing Methods					
	Sun-Dried (T_1)	**Crushed (T_2)**	**Soaked and Milled (T_3)**	**Milled (T_4)**	**Milled with Charcoal (T_5)**	**Dried Sweet Potato Forage**
Tannin	1.20	1.30	0.90	0.10	0.80	0.90
Saponin	0.70	0.52	0.52	0.49	0.49	0.42
Phytate	0.42	0.36	0.36	0.30	0.36	0.36
Cyanide	0.22	0.32	0.22	0.43	0.22	0.32
Oxalate	2.64	3.52	3.08	2.64	3.96	2.98

Table 4.4 Shows the proximate analysis of the experimental diets containing differently processed Acacia pods (T_{1-5}). Acacia milled with charcoal (T_5) had the highest value of crude protein (16.19%), followed by soaked and milled Acacia (T_3) with 15.13%, while sun-dried Acacia (T_1) had the least crude protein (13.06%). Also Acacia with charcoal (T_5) had the highest value of crude fibre (15.29%), followed by sun-dried Acacia T_1 (15.14%); while the least

crude fibre (9.19%) was found in milled Acacia (T_4). Crushed Acacia (T_2), had the highest content of ash 11.78%, followed by sun-dried Acacia pods (T_1) with 10.75%; while the least value of ash (9.02%) was found in milled Acacia pods (T_4). The highest value of ether extract (21.30%) was in soaked and milled Acacia (T_3), followed by crushed Acacia (T_2) having 19.32%; while the least percentage of ether extract (17.63%) was found in milled Acacia pods (T_4). Acacia milled with charcoal (T_5) had the highest value of dry matter (DM) 92.87%, followed by crushed Acacia (T_2) with 95.53%; while the least value of dry matter (91.46%) was found in milled Acacia pods (T_4).

Table 4.4: Chemical Composition of Experimental Diets Containing Differently Processed *A. nilotica* Pods (Expt. I)

Parameters (%)	**Processing Methods**				
	Sun-Dried (T_1)	**Crushed (T_2)**	**Soaked and Milled (T_3)**	**Milled (T_4)**	**Milled with Charcoal (T_5)**
DM	91.65	92.53	92.34	91.46	92.87
Ash	10.75	11.78	10.86	9.02	10.35
CP	13.06	13.78	15.13	14.63	16.19
CF	15.14	9.65	13.74	9.19	15.29
EE	18.02	19.32	21.30	17.63	18.69
NDF	57.94	54.12	56.08	58.16	56.08
ADF	36.10	35.08	36.06	37.04	36.18
NFE	42.46	38.72	44.06	41.10	36.56
*ME (Kcal/kg)	3748	2723	2897	3620	3447

ME = 0.0152 (DCP) + 0.0342 (DEE) + 0.0128 (DCF) + 0.0159 (DNFE).
*According to: Alderman G. (1978).
Where:
ME = Metabolizable energy (Kcal/kg)
DCP = Digestible crude protein
DEE = Digestible ether extract
DCF = Digestible crude fibre
DNFE = Digestible nitrogen free extract.
DM = Dry matter, CP = Crude protein, CF = Crude fibre, EE = Ether extract, NDF = Neutral detergent fibre, ADF = Acid detergent fibre, NFE = Nitrogen free extracts.

4.1.2 Feed Intake and Growth Performance:

The first experimental diets contained a mixture of maize offal, cotton seed cake, *Acacia nilotica* pods (processed in different ways), bone meal and salt (Table 3.1).

Table 4.5 shows the feed intake and growth performance of Red Sokoto goats fed diets containing differently processed Acacia pods. The highest daily intake of experimental diet was recorded in milled Acacia diet (T_4 , 111.20g/day) while the least intake of concentrate was in Acacia milled with charcoal diet (T_5, 84.96g/day). Daily intake of sweet potato forage was significantly different ($P<0.05$) across the treatments; the highest intake was in milled Acacia (T_4) while the least intake was in Acacia milled with charcoal (T_5, 164.58g/day and 128.87g/day respectively). Total daily feed intake differed significantly ($P<0.05$) across the treatments. The highest total daily feed intake was recorded in milled Acacia diet (T_4, 275.78g/day), while the least intake of feed was recorded in Acacia milled with charcoal diet (T_5, 213.82g/day). The final body weights of the animals differed significantly ($P<0.05$) across the treatments. The highest final body weight was recorded in animals fed diet containing sun-dried Acacia pods (10.90kg), while the least body weight (7.40kg) was recorded in animals fed diet containing Acacia milled with charcoal (T_5).

The best feed conversion ratio was recorded in sun-dried Acacia pods diet (0.504); while the least feed conversion ratio was in Acacia milled with charcoal diet (-0.82).

Table 4.5: Performance of Red Sokoto Goats Fed diets containing differently Processed *Acacia Nilotica* Pods

Parameters	Treatments						
	Sun-Dried	**Crushed**	**Soaked and Milled**	**Milled**	**Milled with Charcoal**	**SEM**	**LOS**
Initial Body Weight (kg)	10.40	9.80	10.80	10.20	10.00	0.82	NS
Final Body Weight (kg)	10.90^{a}	10.10^{a}	10.10^{a}	10.10^{a}	7.40^{b}	0.90	*
Daily Intake of Exp. Diet	87.96^{b}	92.17^{ab}	95.31^{ab}	111.20^{a}	84.96^{b}	8.07	*
Daily Sweet Potato Intake (g)	164.09^{a}	151.78^{ab}	153.59^{ab}	164.58^{a}	128.87^{b}	13.86	*
Total Daily Feed Intake (g)	252.05^{ab}	243.94^{ab}	248.90^{ab}	275.78^{a}	213.82^{b}	20.86	*
Weight Gain (g)	500^{a}	300^{b}	-700^{d}	-100^{c}	-2600^{e}	9.26	*
Daily Weight Gain (g)	5.56^{a}	3.33^{a}	-7.78^{ab}	-1.11^{ab}	-28.89^{b}	2.14	*
Feed Conversion Ratio (Feed consumed/gain).	0.504^{a}	0.187^{ab}	-3.56^{b}	-2.76^{b}	-0.82^{b}	0.80	*

a, b means in the same row bearing different superscripts are significantly different (P<0.05) * significant at P<0.05; NS = not significant at P<0.05.
SEM = standard error of means, LOS = Level of Significance.

4.2 NUTRIENT DIGESTIBILITY AND NITROGEN RETENTION

The results of apparent nutrient digestibility and nitrogen retention studies of Red Sokoto goats are presented in Table 4.6. The result showed a moderate (14.67 to 26.02 %) of nitrogen retention across the treatments. However, there were no significant (P>0.05) differences among the treatments. DM digestibility did not differ among the treatments. NDF digestibility differed (P<0.05) across the treatments (33.66-52.00 %). The highest NDF digestibility of 52% was recorded in crushed Acacia pods diet. ADF digestibility also showed significant (P<0.05) differences across the treatments from 27.88-28.19%. The

digestibility of hemicelluloses 46.08 – 52.62 % differed significantly ($P< 0.05$) across the treatments. Nitrogen intake differed significantly ($P<0.05$) across the treatments from 78.57 - 119.79%. The highest intake of nitrogen was in sun-dried Acacia diet, while the least intake was in Acacia and charcoal milled diet. Faecal nitrogen differed significantly ($P<0.05$) across the treatments from 37.86% in soaked and milled Acacia diet to 64.43% in sun-dried Acacia diet. Also urinary nitrogen differed significantly ($P<0.05$) across the treatments from lowest (26.67%) in milled Acacia diet to highest (43.10%) in soaked and milled Acacia diet.

Table 4.6: Nutrient Digestibilitities and Nitrogen Balance in Red Sokoto Goats Fed Diets Containing Differently Processed *Acacia nilotica* Pods and Sweet Potato Forage.

Parameters (%)	Treatments						
	Sun-Dried	**Crushed**	**Soaked and Milled**	**Milled**	**Milled with Charcoal**	**SEM**	**LOS**
DM	54.28	54.27	54.45	54.54	54.37	0.05	NS
CP	69.00^{a}	65.76^{ab}	64.95^{b}	64.81^{b}	64.82^{b}	0.80	*
Ash	66.00^{ab}	62.00^{b}	66.77^{a}	63.00^{b}	65.00^{ab}	0.89	*
EE	49.16^{ab}	48.38^{b}	50.20^{a}	46.93^{c}	43.07^{d}	1.31	*
CF	18.89^{ab}	18.75^{ab}	19.11^{a}	19.09^{a}	18.24^{b}	0.16	*
NDF	35.17^{b}	52.00^{a}	35.53^{b}	33.66^{b}	34.75^{b}	3.46	*
ADF	28.19^{a}	27.94^{b}	28.01^{b}	28.02^{ab}	27.88^{c}	0.05	*
HC	48.85^{b}	46.08^{c}	52.62^{a}	50.01^{b}	48.06^{b}	1.08	*
Water Intake (ml/d)	466.1	450.0	411.3	398.2	423.6	52.5	NS
Nitrogen balance							
N Intake (g/day)	119.79^{a}	109.14^{a}	109.43^{a}	100.14^{a}	78.57^{b}	10.51	*
Faecal N (g/day)	64.43^{a}	51.14^{ab}	37.86^{b}	48.86^{b}	44.71^{b}	6.81	*
Urinary N (g/day)	34.77^{b}	41.99^{a}	43.10^{a}	26.67^{c}	38.33^{a}	6.72	*
N-Retained (g/day)	20.59	16.01	28.47	24.61	14.47	12.39	NS
% of Intake retained	17.19	14.67	26.02	24.58	18.41	11.66	NS

a,b,c means bearing different superscripts in the same row differ significantly, SEM = Standard Error of Means, LOS = Level of Significance at P<0.05, NS = Not significant and * = significant at P<0.05

4.3 BLOOD METABOLITES

Table 4.7 shows the effects of feeding diets containing differently processed *Acacia nilotica* pods on the blood metabolites of Red Sokoto goats. There was no significant differences at (P>0.05) for packed cell volume (PCV), haemoglobin (Hb) and total plasma protein (TPP) across the treatments. However, the plasma urea nitrogen differed significantly (P<0.05) with sun-dried Acacia giving the highest value of 5.08 mmol/l, while the least value of 3.70 mmol/l was recorded in soaked and milled Acacia pods. Also the highest value of creatinine in blood was recorded in sun-dried Acacia pods 90.27µmol/l. The values of creatinine in other treatments did not differ significantly.

Table 4.7: Effects of Differently Processed *Acacia nilotica Pods* on Blood Metabolites of Red Sokoto Goats

Parameters	Treatments (Differently Processed Acacia)						
	Sun-Dried	**Crushed**	**Soaked and Milled**	**Milled**	**Milled with Charcoal**	**SEM**	**LOS**
PCV (%)	27.20	30.90	27.23	26.87	27.73	2.98	NS
Hb (g/dl)	9.03	10.26	9.04	8.93	9.31	0.99	NS
TPP (g/dl)	6.49	6.72	6.66	6.70	6.40	0.36	NS
PUN (mmol/l)	5.08^{a}	3.83^{b}	3.70^{b}	3.92^{b}	4.38^{ab}	0.58	*
Cr (µmol/l)	90.27^{a}	63.93^{b}	62.47^{b}	66.03^{b}	73.90^{b}	11.54	*

a, b means bearing different superscripts in the same row differ significantly; LOS = Level of Significance, SEM = Standard Error of Means, NS = Not Significant; PCV = Packed Cell Volume, Hb = haemoglonin; TPP = Total Plasma Protein; PUN = Plasma Urea Nitrogen; Cr= Creatinin.

4.4 EXPERIMENT II: FEEDING TRIAL WITH SUN-DRIED *ACACIA NILOTICA* PODS (PREFERRED PROCESSING METHOD) AS A REPLACEMENT FOR CSC IN GOATS DIET.

4.4.1 Proximate and Chemical Analyses:

Table 3.2, shows the composition of diets containing sun-dried *A. nilotica* pods to replace cotton seed cake. The chemical analysis of the feeds formed with sun-dried *Acacia nilotica* pods included at different levels (25-100%) are presented in Table 4. 8. The highest crude protein (17.56%) was recorded in zero% Acacia level. The crude protein content of experimental diets decreased as the level of Acacia inclusion increased from 17.50% in (25% Acacia level) to 14.38% in (100% Acacia level). The dry matter content did not differ significantly (P>0.05) across the treatments. The highest dry matter content (DM) was recorded in zero Acacia level, while the least value was recorded in 100% Acacia level (94.41% and 93.21% respectively). The hemicelluloses (HC) content was highest in zero Acacia level (35.32%); followed by 75% Acacia level (30.10%), while the least percentage of hemicelluloses was found in 50% Acacia level (11.52%). The ash content in zero Acacia level was 6.97; the ash content in 25% Acacia level was 6.08 while the least ash content was found in 100% Acacia level.

Table 4.8: Chemical Composition of Diets Containing different levels of Sun-dried *Acacia nilotica* Pods as Replacement for Cotton Seed Cake (Expt. II)

	Treatments (Levels of *A. nilotica*) %				
Parameters (%)	**0**	**25**	**50**	**75**	**100**
Dry Matter	94.41	94.21	93.62	93.69	93.21
Ash	6.97	6.08	4.53	4.90	4.24
Crude Protein	17.56	17.50	15.38	14.50	14.38
Crude Fibre	10.72	13.13	14.26	13.71	14.13
Ether Extract	18.28	18.29	13.48	10.68	13.92
NDF	45.98	29.48	28.20	41.57	28.64
ADF	10.66	12.01	16.68	11.47	14.11
HC	35.32	17.47	11.52	30.10	14.53
*ME (Kcal/kg)	2536	2322	2430	2549	2428

*ME=0.0152(DCP) + 0.0342 (DEE) + 0.0128 (DCF) + 0.0159 (DNFE).

According to: Alderman G. (1978).

4.4.2 Performance of Red Sokoto Goats Fed diets Containing different levels of Sun-Dried *Acacia nilotica* Pods as Replacement for Cotton Seed Cake:

Table 4.9 shows the feed intake, and growth performance ` of Red Sokoto goats fed the experimental diets. There were no significant differences (P>0.05) in daily intake of experimental diets, daily sweet potato intake, daily feed intake, initial body weight and final body weight. However, daily intake of experimental diets declined as the level of sun-dried Acacia inclusion increased from 262.16g in 25% Acacia level to 225.30g in 100% Acacia level. Feed conversion ratio differed significantly (P<0.05) across the treatments, from 8.70g in 25%

Acacia level to 12.77g in 75% Acacia level. Replacing CSC with 25% Acacia had the lowest feed conversion ratio and the least cost in terms of weight gain. Final body weights of animals did not vary significantly (P>0.05) across the treatments; however the highest final body weight of 16.62kg was recorded in 25% Acacia inclusion level; while the least final body weight was recorded in 75% Acacia inclusion level.

Table 4.9: Performance of Red Sokoto Goats Fed Diets Containing Different Sun-Dried *Acacia nilotica* Pods to Replace Cotton Seed Cake

	Treatments (% Levels of *Acacia nilotica replacement of CSC*)						
Parameters	**0**	**25**	**50**	**75**	**100**	**SEM**	**LOS**
Initial Body Weight (kg)	10.30	10.40	10.30	10.30	10.40	1.20	NS
Final Body Weight (kg)	16.30	16.62	15.62	14.14	14.94	1.92	NS
Daily Intake of Exp. diet (g)	256.93	262.16	249.97	228.94	225.30	29.87	NS
Daily Sweet Potato Intake (g)	342.80	339.71	331.34	316.22	330.42	31.50	NS
Daily Feed Intake (g)	599.73	601.87	581.31	545.16	555.72	59.82	NS
Weight Gain (kg)	6.00^{a}	6.22^{a}	5.32^{ab}	3.84^{b}	4.54^{b}	0.86	*
Daily Weight Gain (g)	66.67^{a}	69.11^{a}	59.11^{ab}	42.67^{b}	50.44^{ab}	9.61	*
Feed Conversion Ratio	8.99^{c}	8.70^{c}	9.83^{bc}	12.77^{a}	11.01^{b}	0.84	*
Cost/Weight Gain (₦/kg)	0.61^{ab}	0.55^{a}	0.59^{a}	0.71^{b}	0.56^{a}	0.04	*

a, b, c means in the same row bearing different superscripts are significantly different (P<0.05) level, * = significant at P<0.05; and NS = not significant at P>0.05.

4.4.3 Nutrient Digestibility and Nitrogen Retention:

The results of nutrient digestibility and nitrogen retention studies of Red Sokoto goats fed diets containing different levels of sun dried *Acacia nilotica* pods are presented in Table 4.10. The result showed that nitrogen retention across the treatments did not differ

significantly (P>0.05). It ranged from 93.06 to 124. 90g, in 75% Acacia level and zero Acacia level respectively .The DM digestibility across the treatments did not differ significantly (P>0.05).

The digestibility of ether extract differed slightly (P<0.05) even though it did not follow a defined pattern. The highest value (28.52%) was in zero percent Acacia level, followed by 75%, 50% and 100% Acacia levels, while the least digestibility was recorded in 25% Acacia level (23.56). The digestibility of hemicellulose differed slightly (P<0.05) across levels. The highest value was (37.64%) in 75% Acacia level , while the least value was recorded in 25% Acacia level (27.60). The nitrogen output in the feaces (FN) differed (P<0.05) slightly and also followed a defined pattern. It decreased from zero inclusion to 100% Acacia inclusion, from 78.71 – 51.01g. Water intake differed significantly (P<0.05) across the treatments; the least intake of water was recorded at 50% inclusion of Acacia pods, while the highest intake of water was recorded at 0% inclusion of Acacia pods. Nitrogen intake and faecal nitrogen differed significantly (P<0.05) across the treatments and also followed a defined pattern; they decreased as the level of Acacia pods inclusion increased. Urinary nitrogen recorded in this study differed significantly (P<0.05) from 14.32% at 100 percent inclusion level to 36.11% at 75 percent inclusion level.

Table 4.10: Nutrients Digestibilities and Nitrogen Balance in Red Sokoto Goats Fed different levels of Sun- dried *Acacia Nilotica* Pods as replacement for Cotton Seed Cake.

	Treatments (% Levels of *A. nilotica replacement of CSC*).						
Parameters (%)	**0**	**25**	**50**	**75**	**100**	**SEM**	**LOS**
DM	55.50^{ab}	55.55^{a}	55.47^{ab}	55.38^{b}	55.39^{b}	0.033	*
CP	51.94^{a}	50.69^{b}	51.57^{ab}	50.57^{b}	51.88^{ab}	0.293	*
Ash	57.63^{a}	55.63^{b}	56.79^{ab}	51.18^{d}	53.49^{c}	0.709	*
EE	28.52^{a}	23.56^{c}	25.80^{b}	25.89^{b}	24.83^{c}	0.849	*
CF	22.52^{b}	24.01^{a}	22.30^{b}	23.18^{ab}	21.90^{b}	0.371	*
NDF	33.47^{ab}	34.18^{a}	33.05^{b}	33.77^{ab}	33.32^{b}	0.194	*
ADF	29.20^{a}	30.24^{a}	28.75^{ab}	28.39^{b}	28.74^{ab}	0.321	*
HC	30.36^{c}	27.60^{d}	30.11^{c}	37.64^{a}	32.05^{b}	1.700	*
Water Intake (ml/d)	6922.5^{a}	6300.0^{ab}	5247.5^{b}	6481.3^{ab}	5366.3^{b}	454.6	*
Nitrogen balance							
N Intake (g/day)	234.67^{a}	211.09^{ab}	206.86^{ab}	182.60^{b}	176.03^{b}	21.67	*
Faecal N (g/day)	78.71^{a}	75.29^{a}	73.43^{a}	53.43^{b}	51.01^{b}	7.78	*
Urinary N (g/day)	31.06^{ab}	22.76^{ab}	28.60^{ab}	36.11^{a}	14.32^{b}	10.39	*
N-Retained (g/day)	124.90	113.04	104.83	93.06	110.70	22.02	NS
% of Intake retained	53.22	53.55	50.68	50.96	62.89	8.05	NS

a, b, c means bearing superscripts in a row differ significantly, SEM = Standard Error of Means, LOS = Level of Significance at $P<0.05$, NS = Not significant.

4.4.4 Blood Metabolites:

Figures 1 to 10 show the trend effects of graded levels of sun-dried *A. nilotica* pods on the blood metabolites of Red Sokoto goats; at different periods of collection (beginning, middle and end of experiment) and at different hours of collection (before feeding, and at 3,6,9 and 12 hours after feeding).

There were significant differences in the Packed Cell Volume (PCV), haemoglobin (Hb), Total Plasma Protein (TPP); Plasma Urea Nitrogen (PUN) and creatinine (Cr) across the treatments at ($P<0.05$) for the different periods of blood sampling – at the beginning, middle and end of the experiment (Figures 1-5). There were also significant ($P<0.05$) differences for all the parameters measured across the treatments at different hours of blood sampling after feeding (Figures 6-10).

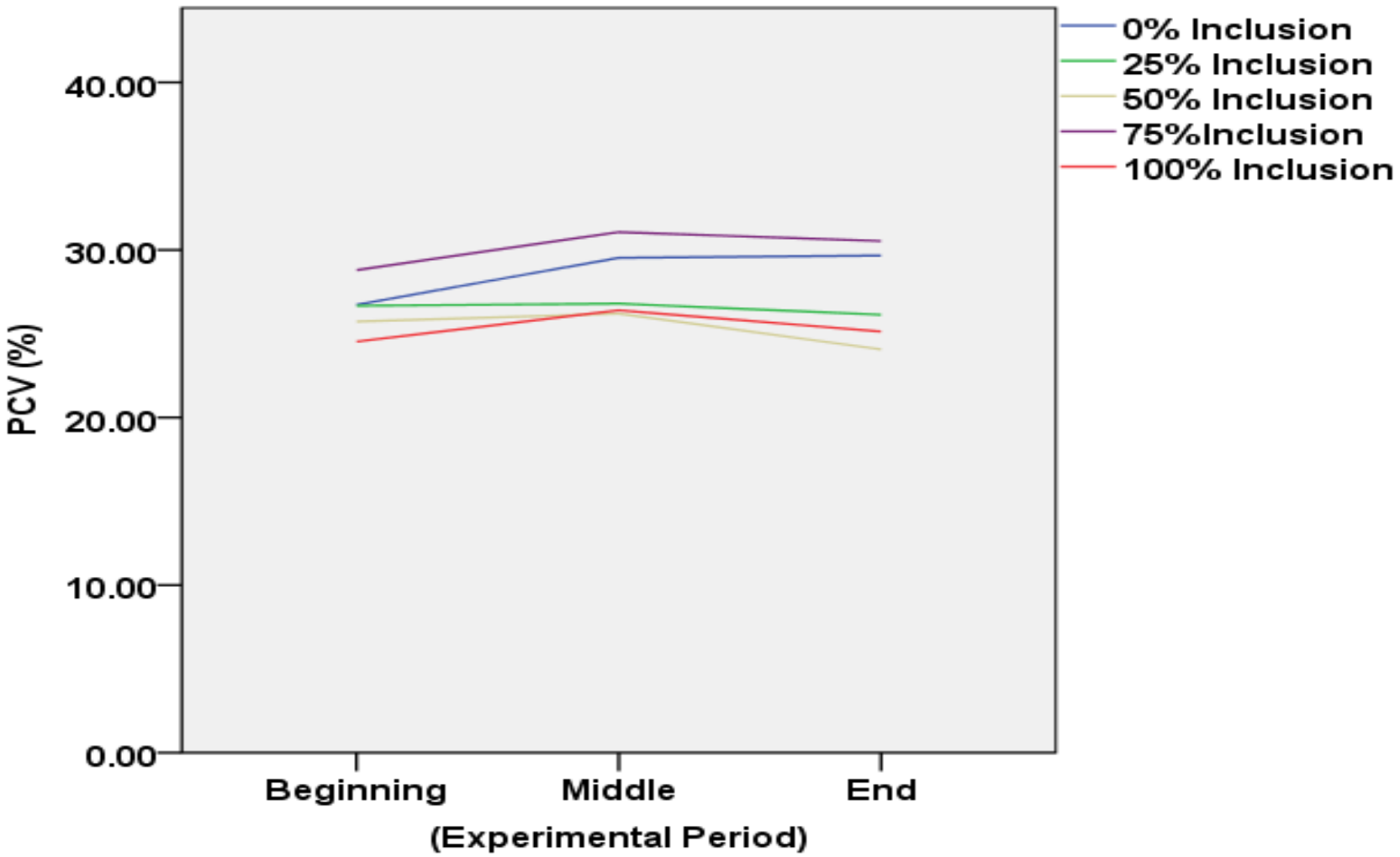


Fig 1: Trend of PCV (%) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different days of collection.

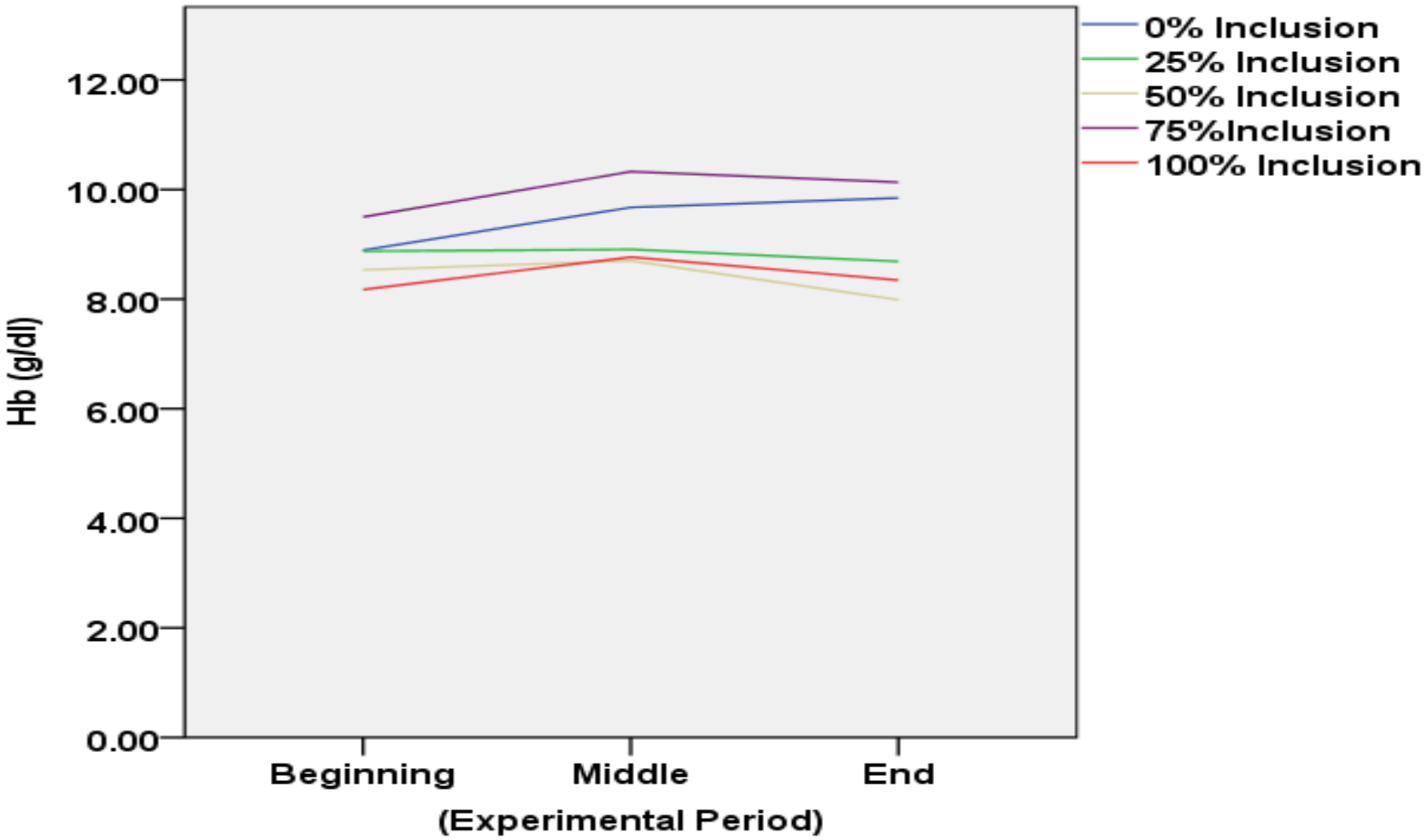


Fig 2: Trend of Hb (g/dl) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different days of collection.

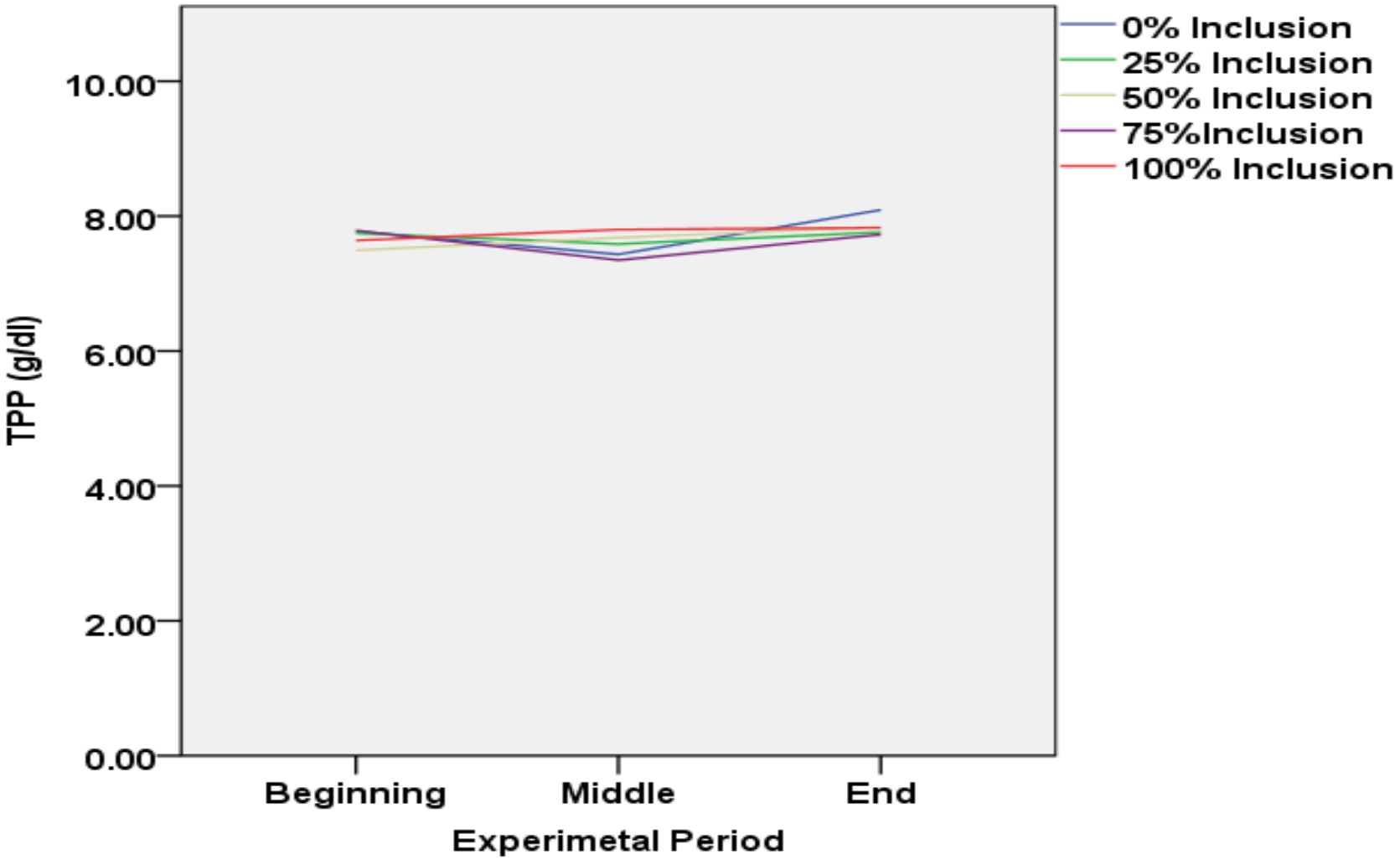


Fig 3: Trend of TPP (g/dl) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different days of collection.

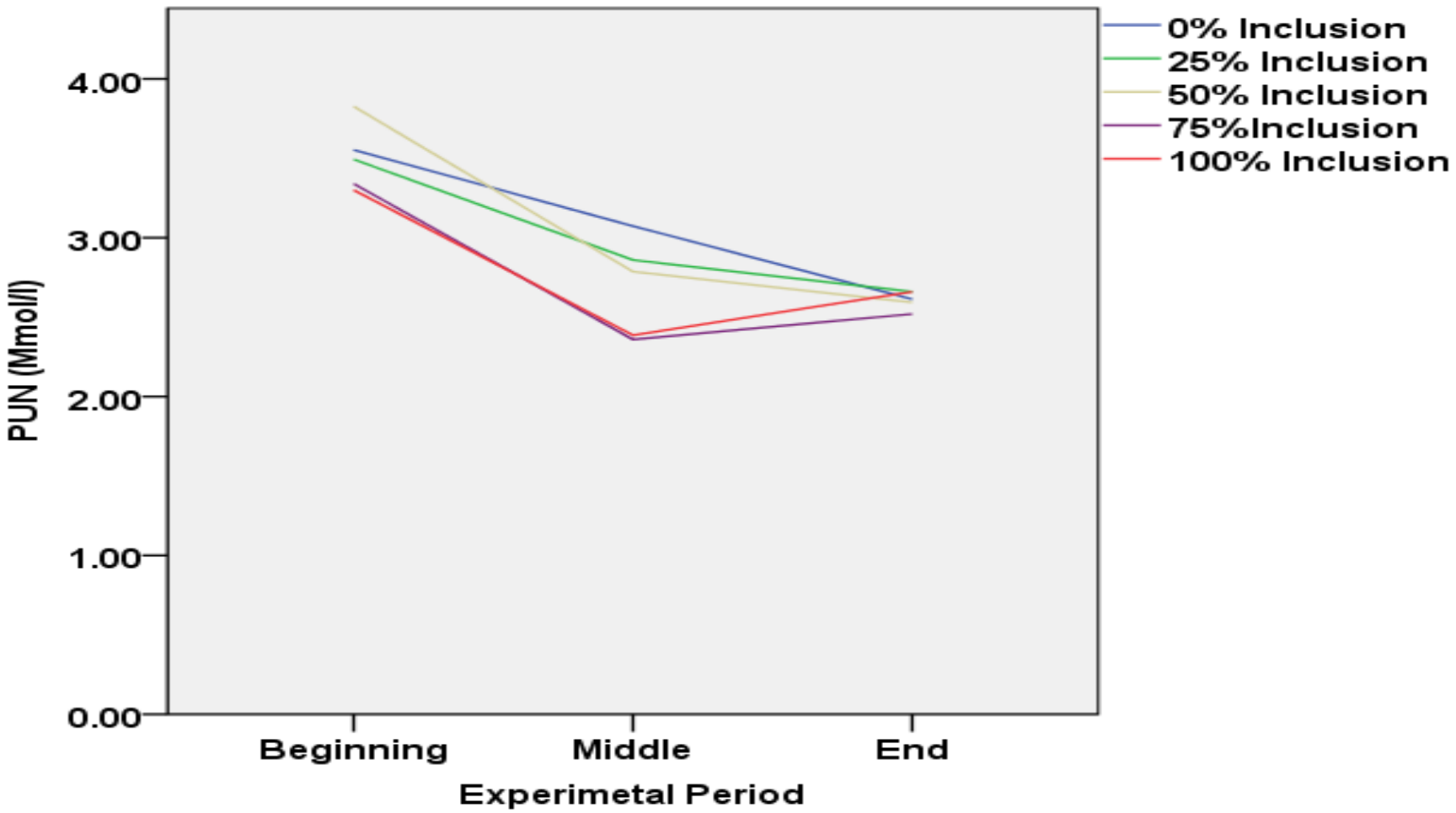


Fig 4: Trend of PUN (Mmol/l) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different days of collection.

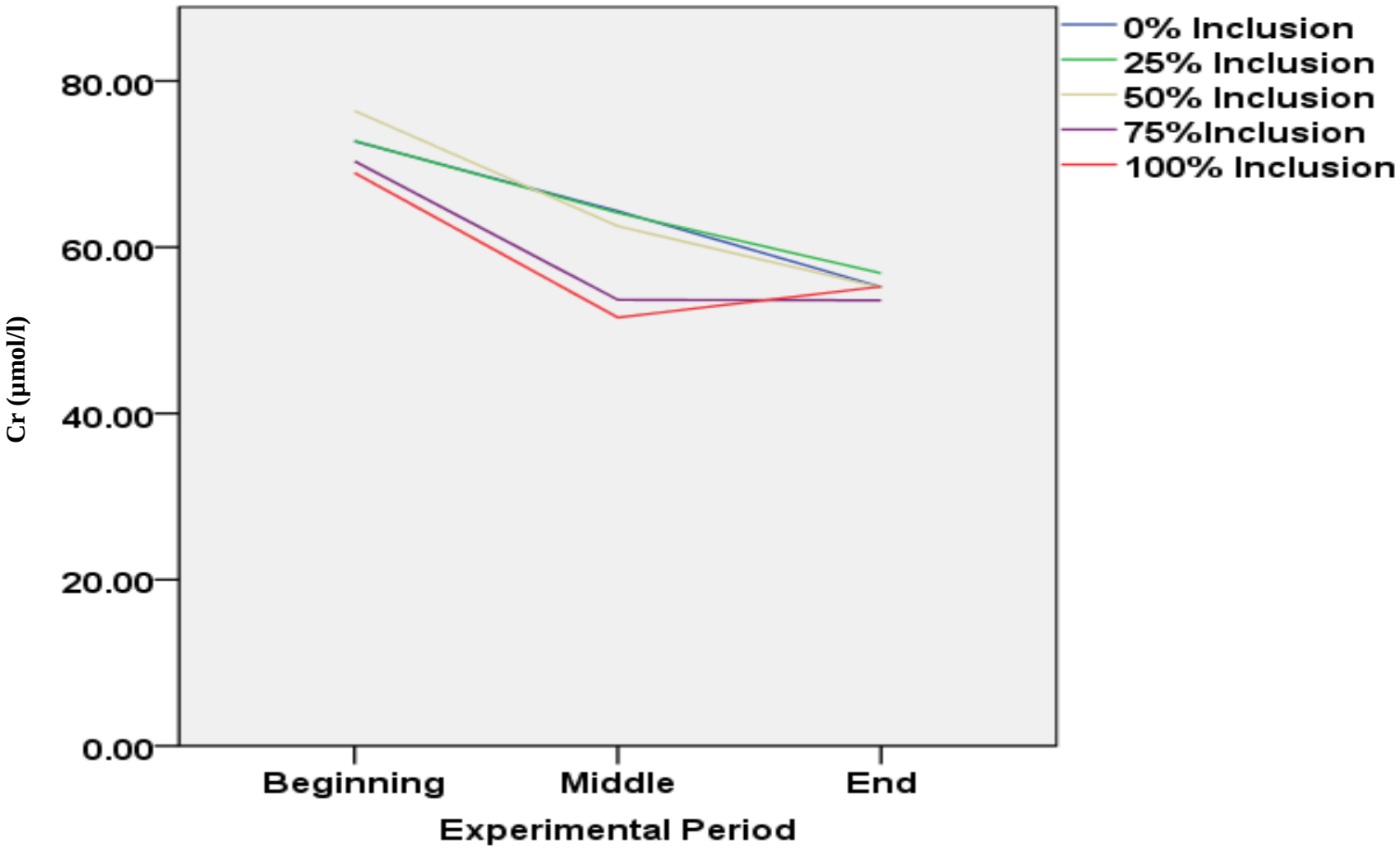


Fig 5: Trend of Cr (µmol/l) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different days of collection.

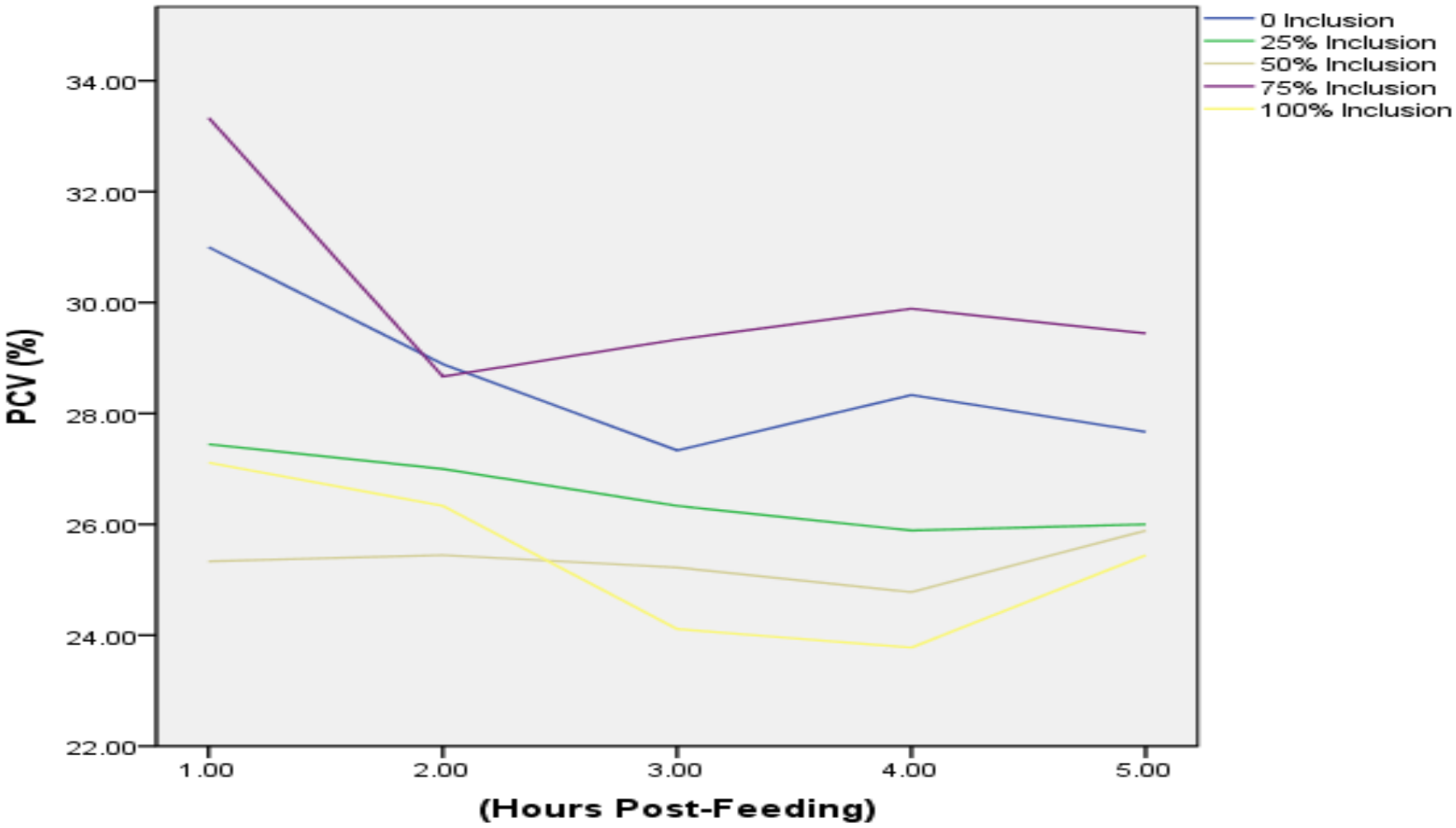


Fig 6: Trend of PCV (%) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different hours of collection.

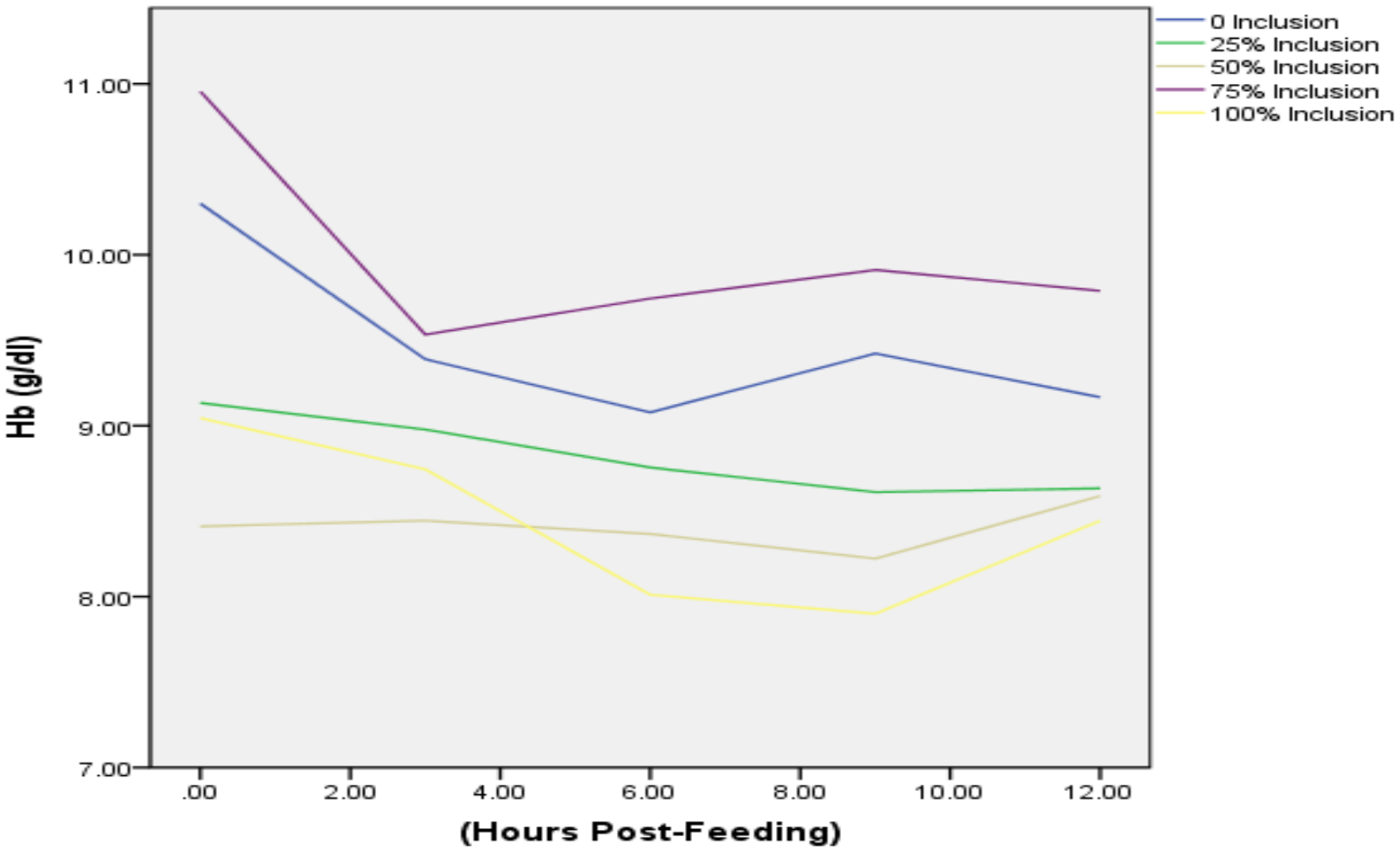


Fig 7: Trend of Hb (g/dl) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different hours of collection.

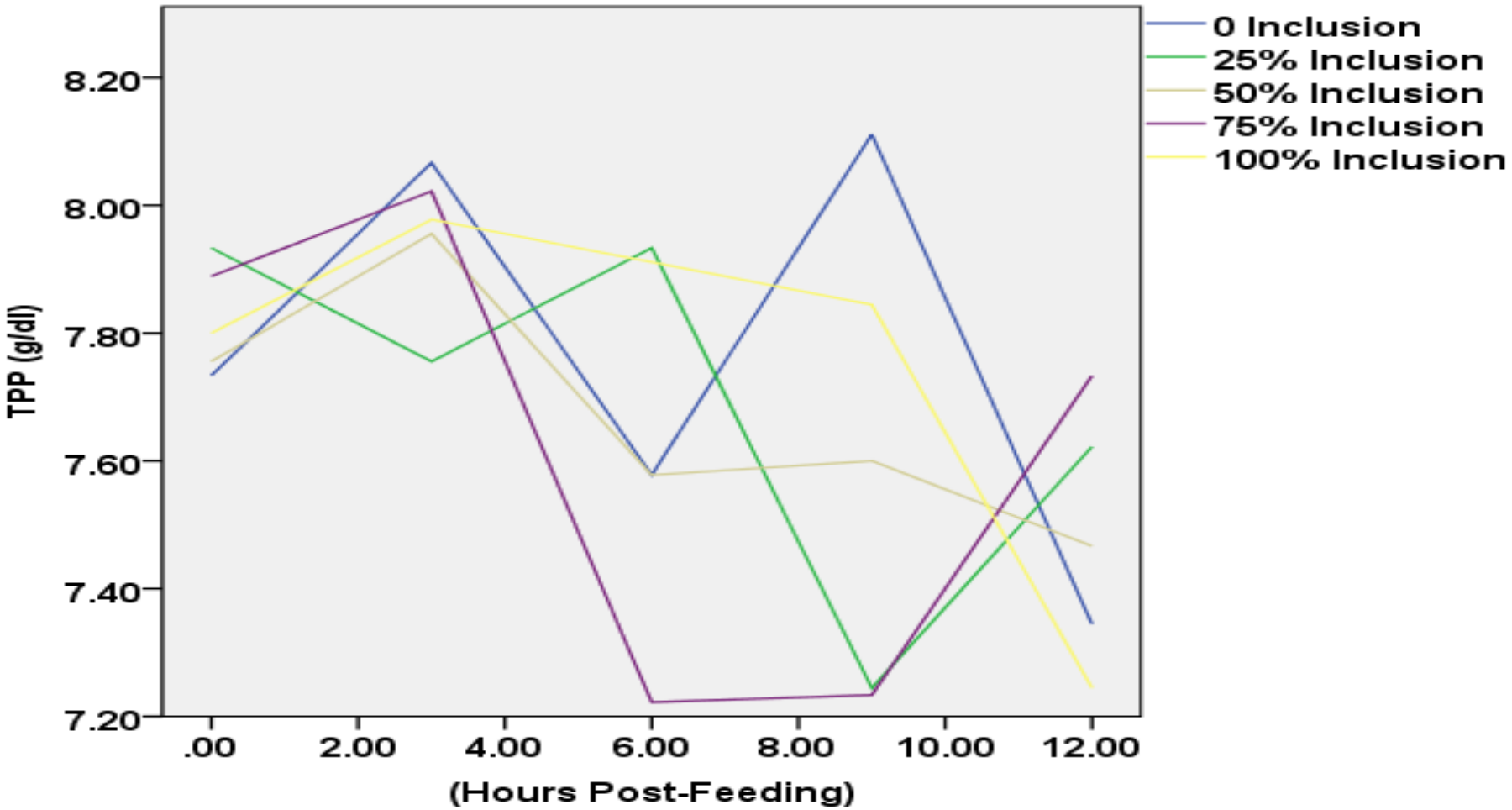


Fig 8: Trend of TPP (g/dl) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different hours of collection.

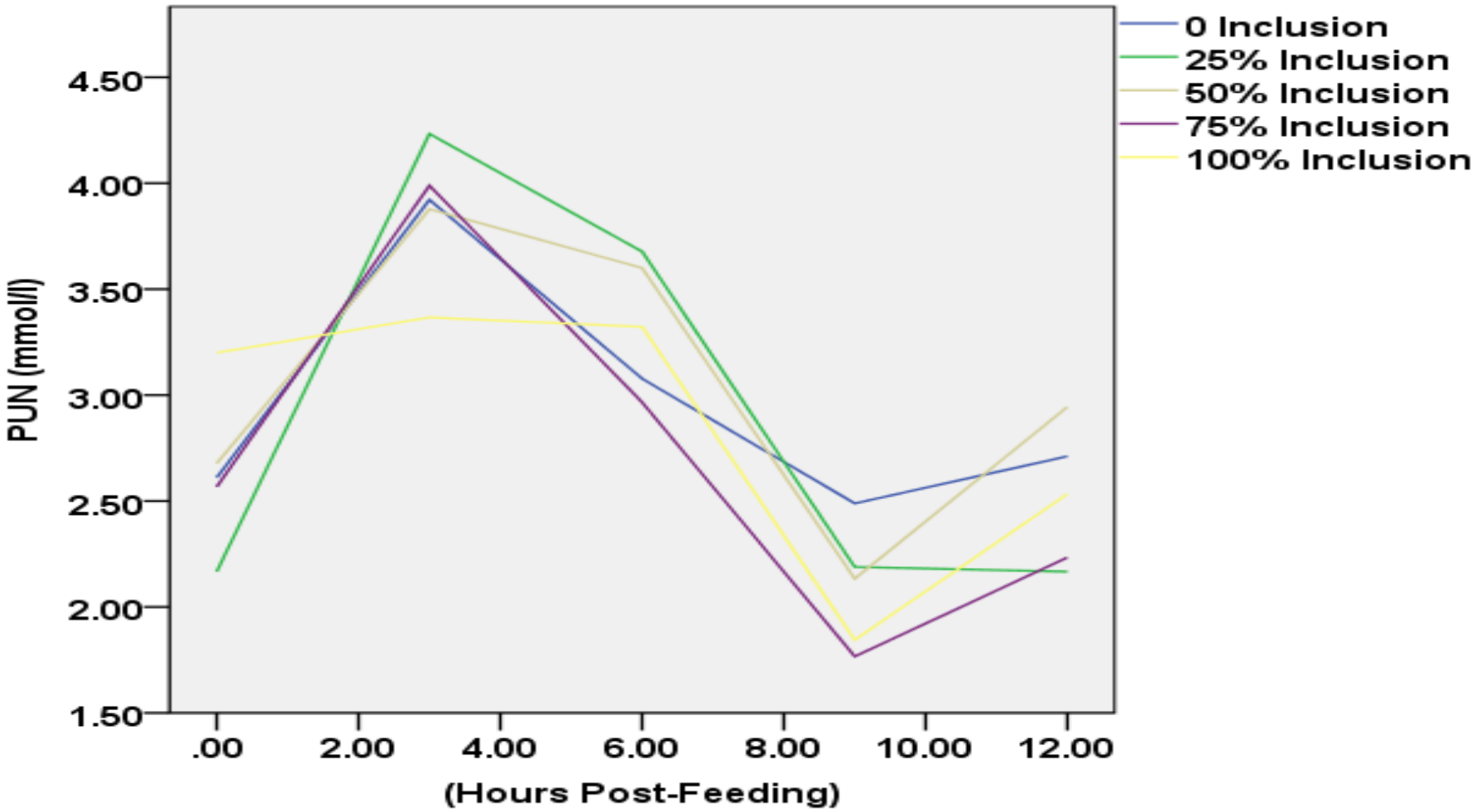


Fig 9: Trend of PUN (Mmol/l) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different hours of collection.

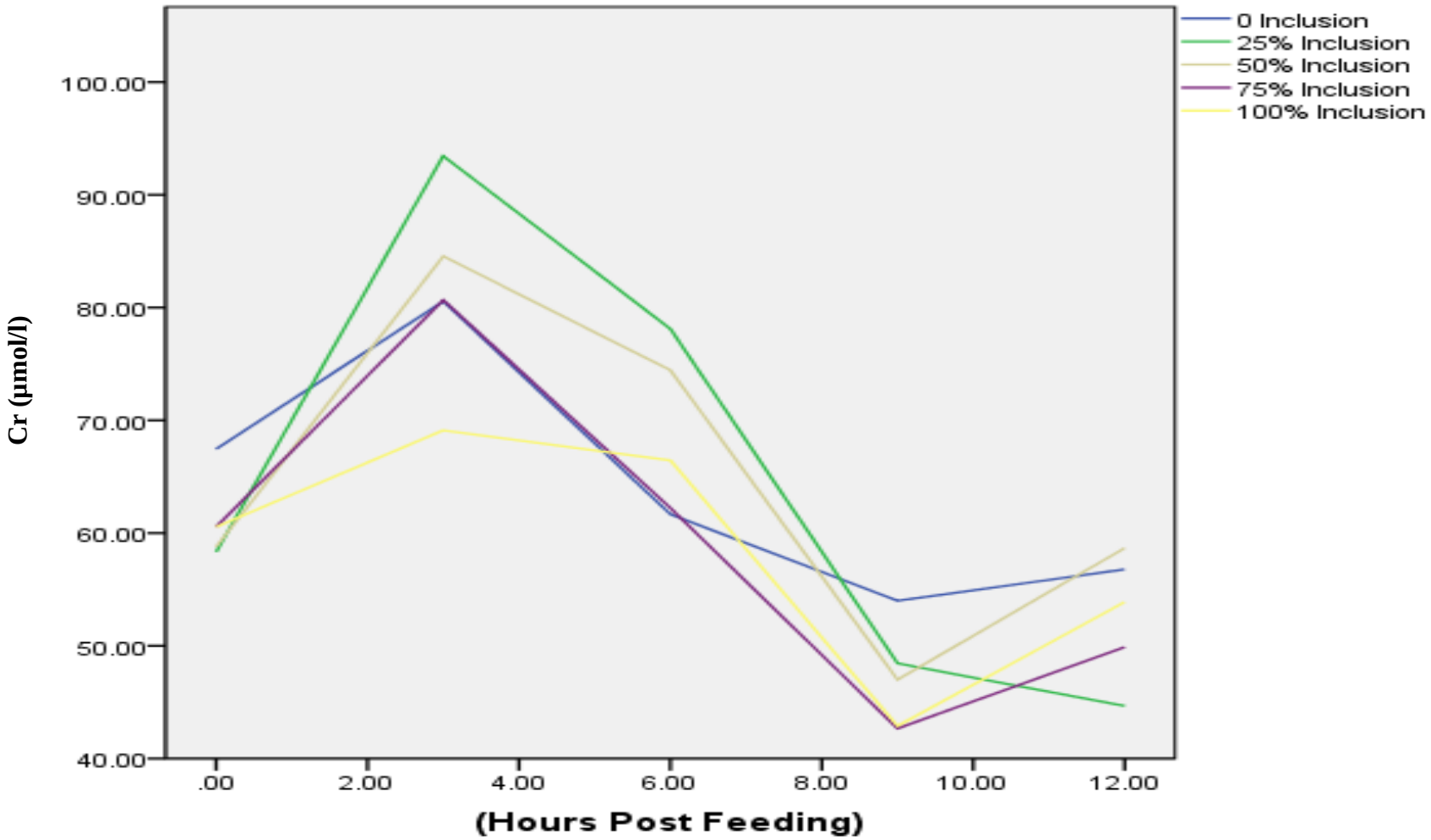


Fig 10: Trend of Cr (µmol/l) of Red Sokoto Goats fed graded levels of *Acacia nilotica* pods at different hours of collection.

CHAPTER FIVE

5.0 DISCUSSION

5.1 FEEDING TRIAL

5.1.1 Feed ingredients:

Acacia nilotica pods can be described as long dark green dried pods containing seeds numbering 5-10. The pod when properly dried is brittle and can easily break when some pressure is applied on it. The cotton seed cake is a dark-yellowish cake that was turned into fine powdery form after undergoing processing by milling. While the sweet potato forage was a mixture of dried leaves and vines chopped into sizeable pieces of 10-20cm to enhance intake by the experimental animals. Calculated portions of *A. nilotica* pods, cotton seed cake, maize offal and other feed ingredients were used to formulate the different rations used in the feeding trials. In the first feeding trial with *A. nilotica* processed in different ways, it was found that the animals preferred whole pods in their diet rather than pods processed in different ways including crushing. The above is in agreement with the findings of Sikosana *et al*., (2002) they reported that the experience of farmers they studied showed that intake of *A. nilotica* pods by goats even though low, the animals preferred whole pods to crushed pods. Positive effect of processing was reported in enhancing digestibility and not intake. According to Aganga *et al* (1998), crushing of seeds of Acacia pods improved digestibility of seeds.

5.1.2 Proximate and energy content of feed ingredient:

The highest crude protein (CP) in differently processed Acacia pods (Experiment I) was in Acacia milled with charcoal (16.19%), while the least CP was found in sun-dried Acacia pods (13.06%). Also the highest CP in sun-dried Acacia pods used as replacement for cotton seed cake (Experiment II) was highest in zero Acacia level (17.56%), while the least CP was found in 100% Acacia level. The above CP values fall within the range of 12-30% reported by

Norton (1998) for most tropical legumes and the range of 10-15% reported by Sikosana *et al* (2002) for most browse plants. Also Rittner and Reed (1992) reported crude protein concentration of 137.5-212.5g/kg DM for West African browse. Leng (1990) reported that the minimum CP content for rumen function is 7-8%; while Meissner (1997) reported that the minimum CP for maintenance is between 70-80g CP/kg DM for ruminants.

5.1.3 Mineral content of feed ingredients:

The mineral content of the sun-dried *A. nilotica* pods are: sodium 0.05%, calcium 4.00 (mg/kg), iron 0.03%, copper 0.00%, zinc 0.01%, magnesium 0.14% and potassium 1.00%. The above falls within the range of minerals recommended by NRC (1985) for small ruminants: 0.21-0.51% calcium, 0.16-0.37% phosphorous, 0.04-0.08% magnesium and 0.04-0.1% sodium. In sheep McDowell *et al*., (1983) recommended the following as mineral requirement for maintaining adult sheep: calcium 2.5g/kg DM, phosphorus 1.5g/kg DM, magnesium 2.0g/kg DM and sodium chloride 3.0g/kg DM. In addition to the above, 10-20% of these minerals should be given to animals on pasture to ensure optimum performance (McDowell *et al*., 1983).

5.1.4 Tannin in *A. nilotica* pods:

The levels of tannin and other anti-nutritional factors in sun-dried *A. nilotica* pods used in this study was within the normal range (2%) for safe animal feeding (Oloyo, 2004). The levels of tannin in the differently processed *A. nilotica* pods varied from 0.10mg - 1.30mg/100g across the treatments. According to Barry and Duncan (1984) the ideal condensed tannin (CT) concentration for ruminant animal nutrition has been suggested to be in the range of 20-40g/kg DM, based on the butanol – Hcl method. Also Yahaya (2011) reported that the concentration of tannin in Acacia species is highest in the seeds followed by the leaves and the fruits. In *Acacia seyal* species, the seed had significantly ($P<0.05$) higher tannin content 0.65mg/100g, followed

by the leaves 0.23mg/100g and the fruits 0.17mg/100g (Yahaya, 2011). The level of tannin in sun-dried Acacia pods was within the range of 5.4% reported by Ehoche *et al* (1983) and 0.17mg/100g reported by Yahaya (2011) in *A. seyal* del. pods.

5.1.5 Feed intake:

Feed intake differed amongst the goats used in the first growth study (Expt .I). The least intake of feed (213.82g) was recorded in the diet containing milled Acacia pods with charcoal; the above low level of intake did not agree with the finding of Poage *et al* (2000); they reported that addition of charcoal in Acacia pod meal can enhance their use in feeding livestock. The intake of feeds did not differ significantly in the second growth study (Expt. II); but the highest total daily feed intake (601.87g) recorded in 25% Acacia level, fall below the values reported by Aganga *et al* (1998). They reported an average daily DM intake of 768.40g and 790g for goats fed *A. fleckii* and *A. tortilis* respectively as supplements. In the second growth study there was no significant difference in the intake of experimental diets as a result of inclusion of *A. nilotica* in the diets. However, intake of experimental diets decreased as the level of Acacia inclusion increased from 25% to 100%. The above is in agreement with the finding of Makaranga (2002); who reported reduction in intake of dry matter and crude protein when sheep were fed with browse diets containing tannins. On the contrary, Araya *et al* (2003); reported that dry matter intake, in-vitro dry and organic matter digestibility and body weight gains increased with an increase in the amount of *A. tortilis* pods in the rations of goats, up to 75% level and then decreased. Araya *et al;* (2003); recommended 75% pods supplementation level as the maximum. In a study with sheep fed *Acacia seyal*, Yahaya (2011); reported that inclusion of *A. seyal* in the diet had no effect on voluntary dry matter intake. This agrees with the

findings of Forbes (2000) who reported that voluntary intake is controlled by physiological, metabolic and physical forms of feed.

5.1.6 Weight changes and feed efficiency:

Weight gain by goats in Experiment I differed significantly; those that received sun-dried Acacia pod diet performed better than those in other treatments. In Experiment II, weight gain, feed conversion ratio and cost per weight gain differed amongst the experimental animals. The highest weight gain in Experiment II (6.22kg) recorded in 25% Acacia inclusion was similar to the value of 6.23kg reported by Yahaya (2011); when varied levels of *A. seyal Del.* Was used as replacement for cotton seed cake in sheep. Generally it was observed that increasing levels of Acacia pods affected performance of experimental animals negatively; may be because of higher levels of tannin in such diets. This agrees with the finding of Reed (1986) and Tanner *et al*. (1990); they reported that polyphenolic compounds can complex with protein to cause substantial reduction in feed digestion rate and consequently affect feed utilization. Also Robbins *et al*., (1987) and Salem *et al*., (2006) reported that ingestion of tannin – containing food by ruminants may reduce digestibility, particularly that of protein and voluntary intake. Bejovic *et al*., (1978) reported that tannin levels of 8-10% in the diet can have negative effect in sheep and goats.

5.2 NUTRIENTS DIGESTIBILITIES AND NITROGEN BALANCE

Digestibility of most feed nutrients differed in Experiment I and II. Digestibility of ether extract was better in 0% Acacia level than in the other treatments. The low digestibility of EE in the other treatments containing varying levels of Acacia pods may have been caused by the increasing levels of tannin in them. This agrees with the findings of Robbins *et al.* (1987) and Salem *et al*. (2006) who reported that ingestion of tannin-containing food by ruminants reduced

digestibility, particularly that of protein and voluntary intake. In Experiment II, nitrogen intake differed significantly across the treatments and decreased as the level of Acacia inclusion increased. This result agrees with the findings of Makaranga (2002) and Salem *et al.* (2006); they reported that ingestion of tannin-containing food by ruminants may reduce digestibility of feed nutrients (particularly protein) and voluntary intake. Faecal nitrogen in Experiment II decreased as the level of Acacia inclusion increased; the above was not in agreement with the finding of Van Soest (1994) and Karda *et al.* (2001), they reported that increasing levels of tannin in diets also led to increase in feacal nitrogen excretion because of low digestibility of nitrogen and the formation of tannin protein complexes. A possible explanation for low nitrogen excretion amongst the experimental animals may be the formation of tannin-protein complexes in the stomach of such animals (Araya *et al.* 2003). Another reason may be the relatively high levels of urinary nitrogen recorded in 25 to 75% Acacia inclusion levels. Urinary nitrogen differed amongst the animals in Experiment II, however, contrary to the finding of Van Soest (1994); that animals on high tannin content feeds retained nitrogen by reducing nitrogen excretion through urine, this was true only at 100% inclusion of Acacia pods (14.32%). Nitrogen retention did not vary significantly in Experiment II, and did not increase as the level of Acacia inclusion increased as reported by Van Soest (1994), Umunna *et al.* (1995), and Kaitho *et al.* (1998). A possible explanation for this may be that contrary to the findings of the above authors that animals on high tannin contents retained nitrogen by reducing nitrogen excretion through urine; in this study animals in 25 to 75% Acacia inclusion had higher urinary nitrogen excretion (22.76, 28.60, and 36.11% respectively). It was only in 100% Acacia inclusion level that urinary nitrogen excretion (14.32%) reduced remarkably.

Water intake amongst the animals in Experiment I did not differ significantly; while water intake differed amongst the experimental animals in Experiment II. In Experiment II Animals in treatment I (0%) , inclusion of Sun-dried Acacia pods had the highest intake of water 6922.5 (ml/dl). High intake of water by animals in treatment 1, may have been caused by the oily and fibrous nature of cotton seed cake.

5.3 BLOOD METABOLITES

The range of blood metabolites recorded in Experiments I and II fall within the normal range recommended for goats. However, maybe because of the effect of processing Acacia pods; animals in Experiment I, gave better results in the values of Plasma urea nitrogen (PUN) and Creatinine (Cr). The values of PUN ranged from 3.70 to 5.08 mmol/l in animals fed diets containing differently processed Acacia pods ; while the values of PUN for those fed graded levels of sun-dried Acacia pods was 1.84 to 4.45 mmol/l. This agrees with the finding of Reed *et al.* (1990); who reported that high concentration of tannin in diets affects the level of PUN negatively as was the case at 100% inclusion of sun-dried Acacia Pods. Also while the values of creatinine for animals fed diets containing differently processed Acacia pods (Expt.I) ranged from 62.47 to 90.27µmol/l; the values for those fed graded levels of sun-dried Acacia pods (Expt.II) ranged from 41.93 to 87.87µmol/l.

5.3.1 Haematological parameters in Expt.I:

The range of packed cell volume (PCV) in Expt.I, 26.87 to 30.90 % for different periods of sampling was within the normal range of 24 to 45% recommended for caprine species by Ganti (1983). The above values of PCV is also within the range of 1.50ml/g and 3.00ml/g reported by Mokoboki *et al.* (2005) in animals fed *A. Karroo* and *A. herbeclada* respectively. The range of haemoglobin (Hb g/dl), 8.93 to 10.26 g/dl was also within the normal range of 8 to

15 g/dl recommended for caprine species by Ganti (1983). Total plasma protein (TPP), 6.4 to 6.72 g/d was within the normal range of 6.4 to 7.0 g/dl recommended for caprine species by Kaneko (1989). The range of plasma urea nitrogen (PUN), 3.70 to 5.08 mmol/l was within the range of 2.5 to 6.5 mmol/l recommended for goats by Mehrez (1976). Also the range of creatinine (Cr) in Expt.I, 62.47 to 90.27 µmol/l was within the range of 88.40 to 159.00 µmol/l recommended for goats by Kaneko *et al.* (1997). The above results shows that inclusion of differently processed *A.nilotica* pods in the diets of Red Sokoto goats had no negative effect on their haematological parameters.

5.3.2 Haematological parameters in Expt.II:

The range of PCV (23.53 to 33.20%), Hb (7.79 to 11.03 g/dl), and TPP (6.48 to 8.58 g/dl) respectively in Expt.II, falls within the range of packed cell volume, haemoglobin and total plasma protein recommended by Ganti (1983) and Kaneko (1989) respectively for goats. However, the levels of plasma urea nitrogen (PUN), 1.84 to 4.45 mmol/l and creatinine (Cr), 41.93 to 87.87 µmol/l falls below the levels recommended by Mehrez (1976) and Kaneko *et al*. (1997) respectively for the caprine species. The low level of PUN recorded in Expt. II, may have been caused by higher levels of tannin as the inclusion of Acacia pods in the diets increased; this agrees with the finding of Reed *et al.* (1990), they reported that higher levels of tannin in the diets of ruminants will affect the level of PUN negatively (as was the case in 100% inclusion level of Acacia pods). The levels of creatinine recorded in Expt. II, even though below the levels recommended by Kaneko *et al.* (1997); may be described as good because high blood creatinine has been associated with weak or diseased kidneys leading to poor filtration in the kidneys due to muscle catabolism (Wisloff *et al*. 2003).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

In Expt. I, feeding differently processed *A. nilotica* pods affected the intake of feed, feed conversion ratio and final body weight amongst Red Sokoto goats. It also affected the digestibility of some feed nutrients like crude protein, ether extracts, neutral detergent fibre and hemicellulose. Differently processed *A. nilotica* pods also significantly affected nitrogen intake and faecal nitrogen in Red Sokoto goats. Sun-dried acacia pods gave the best result in most of the parameters measured.

In Expt. II, feeding graded levels of sun-dried *A. nilotica* as replacement for cotton seed cake in experimental diets did not significantly affect feed intake in Red Sokoto goats. However, there were significant differences in weight gain, daily weight gain, feed conversion ratio and cost (₦) per weight gain (kg). Feeding graded levels of sun-dried *A. nilotica pods* significantly affected the digestibility of ether extract, crude fibre, acid detergent fibre and hemicellulose; it also affected nitrogen intake, faecal nitrogen, and urinary nitrogen in Red Sokoto goats, as well as most of the haematological parameters and blood metabolites (PCV, Hb, TPP, PUN, and Cr) measured in this Experiment .

From the aforementioned the following conclusions are made:

- Processing *A. nilotica* pods by sun-drying is preferred to other methods of processing used in terms of daily feed intake, feed conversion ratio, final body weight and processing cost.
- The levels of some anti-nutritional factors (Tannin) in *A. nilotica* pods, were found to be within the tolerable levels for goats.

- Feed cost of Red Sokoto goats can be reduced by replacing cotton seed cake in their diets with sun-dried *A. nilotica* pods; 25% replacement level is the best level.

6.2 RECOMMENDATIONS

- Sun-dried Acacia pods can be used to maintain body weight of goats and improve their general well-being; particularly during period of feed scarcity. Twenty five percent (25%) of cotton seed cake in their diets can be replaced with sun-dried Acacia pods to help reduce cost of feeding and ensure regular availability of animal protein and at affordable prices.
- Small-holder farmers should be educated on the benefits of *A. nilotica (L.) Del*., as alternative source of protein to livestock. This will encourage better management of *A. nilotica* plants and ensure stability in the availability of the feedstuff for all year round livestock feeding.
- Also further study should be carried out to determine possible constituents of *Acacia nilotica* pods that caused poor growth performance in Red Sokoto goats; particularly in the groups that had high nitrogen retention.

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APPENDICES

Appendix 1: Baseline Information of the Experimental Animals

Treatments	NOS	Parameters PCVC (%)	Hb (g/dl)	T.P.P (g/dl)
T_1	1	32	10.6	7.2
	2	24	8.0	7.0
	3	32	10.6	8.0
	4	24	8.0	7.0
	5	27	9.0	8.2
T_2	6	28	9.3	8.0
	7	18	6.0	7.8
	8	34	11.3	8.2
	9	30	10.0	7.0
	10	26	8.6	8.0
T_3	11	33	11.0	8.4
	12	30	10.0	6.4
	13	30	10.0	6.4
	14	27	9.0	8.2
	15	24	8.0	5.9
T_4	16	27	9.0	7.2
	17	38	12.6	9.0
	18	30	10.0	9.0
	19	47	15.6	9.6
	20	22	7.3	7.4
T_5	21	32	10.6	8.0
	22	30	10.0	7.8
	23	31	10.3	8.0
	24	20	6.6	8.0
	25	30	10.0	8.2

Parameters	Treatments T_1	T_2	T_3	T_4	T_5
PCV	27.8	27.2	29.6	32.8	28.6
Hb	9.24	9.04	9.90	10.90	9.50
TPP	7.48^{ab}	7.80^{ab}	7.34^{b}	8.44^{a}	8.00^{ab}

a,b means in the same row bearing different superscript are significantly different at ($P<0.05$) level.

Appendix 2: *calculated metabolizable energy ME (Kcal/kg) of experimental diets, 1.

T_1	0.0152 (69) + 0.0342 (49.16) + 0.0128 (18.89) + 0.0159 (48.85)	=	3748
T_2	0.0152 (65.76) + 0.0342 (48.38) + 0.0128 (18.75) + 0.0159 (46.08)	=	2723
T_3	0.0152 (64.95) + 0.0342 (50.20) + 0.0128 (19.11) + 0.0159 (52.62)	=	2897
T_4	0.0152 (64.81) + 0.0342 (46.93) + 0.0128 (19.09) + 0.0159 (50.01)	=	3620
T_5	0.0152 (64.82) + 0.0342 (43.07) + 0.0128 (18.24) + 0.0159 (48.06)	=	3447

* According to: Alderman G. (1978)

ME = 0.0152 (DCP) + 0.0342 (DEE) + 0.0128 (DCF) + 0.0159 (DNFE).

Where

ME = Metabolizable energy (Kcal/kg)

DCP = digestible crude protein

DEE = digestible ether extract

DCF = digestible crude fibre

DNFE = digestible nitrogen free extract

Appendix 3: *calculated Metabolizable energy ME (Kcal/kg) of experimental diets, 2.

T_1	0.0152 (51.94) + 0.0342 (28.52) + 0.0128 (22.52) + 0.0159 (30.36)	=	2536
T_2	0.0152 (50.69) + 0.0342 (23.56) + 0.0128 (24.01) + 0.0159 (27.60)	=	2322
T_3	0.0152 (51.57) + 0.0342 (25.80) + 0.0128 (22.30) + 0.0159 (30.11)	=	2430
T_4	0.0152 (50.57) + 0.0342 (25.89) + 0.0128 (23.18) + 0.0159 (37.64)	=	2549
T_5	0.0152 (51.88) + 0.0342 (24.83) + 0.0128 (21.90) + 0.0159 (32.05)	=	2428

* According to: Alderman G. (1978)

ME = 0.0152 (DCP) + 0.0342 (DEE) + 0.0128 (DCF) + 0.0159 (DNFE).

Where

ME = Metabolizable energy (Kcal/kg)

DCP = digestible crude protein

DEE = digestible ether extract

DCF = digestible crude fibre

DNFE = digestible nitrogen free extract

Appendix 4: Calculated Costs of Experimental Diets

Treatments 1 (0% Acacia)			
Ingredients	**Proportion (%)**	**Unit cost (₦)**	**Total**
Maize offal	30	40	₦1, 200
Cotton seed cake	19	60	₦1, 140
Bone meal	0.75	50	₦37.50
Salt	0.25	75	₦18.75
Sweet potato	20	50	₦1, 000
			₦3, 396.25k
Treatments 2 (25% Acacia)			
Ingredients	**Proportion (%)**	**Unit cost (₦)**	**Total**
Maize offal	30	40	₦1, 200
Acacia pods	4.75	16	₦76
Cotton seed cake	14.25	60	₦855
Bone meal	0.75	50	₦37.50
Salt	0.25	75	₦18.75
Sweet potato	20	50	₦1, 000
			₦3, 187.25k
Treatments 3 (50% Acacia)			
Ingredients	**Proportion (%)**	**Unit cost (₦)**	**Total**
Maize offal	30	40	₦1, 200
Acacia pods	9.5	16	₦152
Cotton seed cake	9.5	60	₦570
Bone meal	0.75	50	₦37.50
Salt	0.25	75	₦18.75
Sweet potato	20	50	₦1, 000
			₦2, 978.25k
Treatments 4 (75% Acacia)			
Ingredients	**Proportion (%)**	**Unit cost (₦)**	**Total**
Maize offal	30	40	₦1, 200
Acacia pods	14.25	16	₦228
Cotton seed cake	4.75	60	₦285
Bone meal	0.75	50	₦37.50
Salt	0.25	75	₦18.75
Sweet potato	20	50	₦1, 000
			₦2, 769.25k
Treatments 5 (100% Acacia)			
Ingredients	**Proportion (%)**	**Unit cost (₦)**	**Total**
Maize offal	30	40	₦1, 200
Acacia pods	19	16	₦304
Bone meal	0.75	50	₦37.50
Salt	0.25	75	₦18.75
Sweet potato	20	50	₦1, 000
			₦2, 560.25k

Appendix 5: Blood sampling at beginning, middle and end of Experiment

		Inclusion Levels of Acacia Pods (%)				
Period	**Parameters**	**(0)**	**(25)**	**(50)**	**(75)**	**(100)**
Beginning	PCV	29.66	25.66	26.33	28.66	27.33
	Hb	9.29	8.24	8.32	9.32	8.46
	TPP	6.51	6.48	6.54	6.52	6.92
	PUN	2.54	2.40	2.51	2.04	1.84
	CR	55.80	53.80	54.67	48.00	41.93
Middle	PCV	26.60	25.26	23.53	28.93	23.80
	Hb	8.84	8.40	7.79	9.60	7.90
	TPP	8.49	8.50	8.58	8.34	8.44
	PUN	4.45	4.29	4.20	4.14	3.80
	CR	87.46	87.87	85.13	83.46	77.13
End	PCV	30.93	29.53	27.40	33.20	26.87
	Hb	10.28	9.82	9.10	11.03	8.92
	TPP	8.29	8.10	7.88	8.00	7.90
	PUN	2.24	2.32	2.50	2.03	2.70
	CR	49.00	52.13	54.26	46.13	56.67

Appendix 6: Effects of different times of Blood sampling on Blood Metabolites in Red Sokoto goats fed different levels of *Acacia nilotica* pods

		Levels of Inclusion (%)				
Time	**Parameters**	**(0)**	**(25)**	**(50)**	**(75)**	**(100)**
Before feeding	PCV	31.00	27.44	25.33	33.33	27.11
	Hb	10.30	9.13	8.41	10.96	9.04
	TPP	7.73	7.93	7.75	7.89	7.80
	PUN	3.20	2.76	2.79	2.74	2.84
	CR	67.44	58.33	58.78	60.56	60.56
3 hours after	PCV	28.88	27.00	25.44	28.67	26.33
	Hb	9.39	8.98	8.44	9.53	8.74
	TPP	8.06	7.76	7.96	8.02	7.98
	PUN	3.92	4.23	3.88	3.99	3.37
	CR	80.55	93.44	84.56	80.67	69.11
6 hours after	PCV	27.33	26.33	25.22	29.33	24.11
	Hb	9.07	8.76	8.37	9.74	8.01
	TPP	7.58	7.93	7.58	7.22	7.91
	PUN	3.08	3.68	3.60	2.97	3.32
	CR	61.67	78.11	74.44	62.22	66.44
9 hours after	PCV	28.33	25.88	24.78	29.88	23.78
	Hb	9.42	8.61	8.22	9.91	7.90
	TPP	8.11	7.24	7.60	7.23	7.84
	PUN	2.49	2.19	2.13	1.77	1.84
	CR	54.00	48.44	47.00	42.67	42.89
12 hours after	PCV	27.67	26.00	25.89	29.44	25.44
	Hb	9.17	8.63	8.59	9.79	8.44
	TPP	7.34	7.62	7.47	7.73	7.24
	PUN	2.71	2.17	2.94	2.33	2.53
	CR	56.78	44.67	58.67	49.89	53.89