EFFECTS OF UREA AND LIME TREATED GROUNDNUT SHELL IN MIXED DIETS ON NUTRIENT INTAKE AND *in situ* DEGRADATION IN YANKASA RAMS

BY

Jacob Jafiya MILLAM
(MSC/AGRIC/36758/12-13)

DEPARTMENT OF ANIMAL SCIENCE

AHMADU BELLO UNIVERSITY, ZARIA

NIGERIA.

OCTOBER, 2016

EFFECTS OF UREA AND LIME TREATED GROUNDNUT SHELL IN MIXED DIETS ON NUTRIENT INTAKE AND *in situ* DEGRADATION IN YANKASA RAMS

BY

Jacob Jafiya MILLAM B. Agric. (MAIDUGURI) 2011
(MSC/AGRIC/36758/12-13)

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER OF SCIENCE DEGREE IN ANIMAL SCIENCE.

DEPARTMENT OF ANIMAL SCIENCE,
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

OCTOBER, 2016

DECLARATION

I declare that the work in this thesis entitled “**EFFECTS OF UREA AND LIME TREATED GROUNDNUT SHELL IN MIXED DIETS ON NUTRIENT INTAKE AND *in situ* DEGRADATION IN YANKASA RAMS**” has been carried out by me in the Department of Animal Science under the supervision of Dr S. B. Abdu and Dr S. M. Otaru. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any other Institution.

Jacob Jafiya MILLAM **Date**

CERTIFICATION

This thesis titled “EFFECTS OF UREA AND LIME TREATED GROUNDNUT SHELL IN MIXED DIETS ON NUTRIENT INTAKE AND *in situ* DEGRADATION IN YANKASA RAMS” meets the regulation governing the award of the degree of Master of Science of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Dr S. B. Abdu
Chairman, Supervisory Committee

Date

Dr S. M. Otaru
Member, Supervisory Committee

Date

Prof S. Duru
Head of Department

Date

Prof K. Bala
Dean, School of Postgraduate Studies

Date

ACKNOWLEDGEMENT

I am eternally grateful to God for making it possible for me to carry out this research work successfully. He has been my anchor. I also wish to express my sincere gratitude to my supervisors, Dr S.B. Abdu and Dr S.M. Otaru for their guide, commitments and untiring efforts in providing the necessary information and resources that enabled the production of this work.

My parents, Mr and Mrs Jafiya Millam and siblings have been of immense help and support. I cannot thank them enough.

My thanks also go to my friends and colleagues such as Mallam Dahiru Gani and Mr Micheal Agumbiade for their support, Reuben and Late Benji of the Department of Animal Science Teaching and Research Farm, are greatly acknowledged for their assistance during the research. I also thank Dr Andrew Austin and Dr Bala of the Faculty of Veterinary Medicine, A.B.U. Zaria for their help and effort to fistulate my rams before the research began and also, Manir of the Veterinary post mortem Lab.

If I continue to mention names, I will not finish. I want to express my sincere gratitude to all the staff and students of the Department of Animal Science, Ahmadu Bello University, Zaria. I really enjoyed a good learning and working relationship with you all.

ABSTRACT

The effects of alkali chemical treatment using urea, lime and urea-lime on the nutritive value of groundnut shell (GNS) were examined based on chemical composition, degradation characteristics, voluntary intake, nutrient digestibility, and nitrogen balance. The treatment diets, T1, T2, T3, and T4 contained untreated (UT) GNS, urea treated (U) GNS, lime treated (L) GNS and urea-lime treated (UL) GNS respectively mixed with maize offal, cotton seed cake, bone meal and salt; were fed to 4 yearling Yankasa rams in a 4×4 Latin square arrangement with four periods of 15 days. The animals were kept in individual metabolism cages. The GNS were treated with 5% urea, 5% lime and 5% (2.5% urea and 2.5% lime mixed together) urea-lime, ensiled for a period of 3 weeks. The diets were formulated to contain 14% crude protein. Feed was offered without restriction and water was supplied *ad libitum.* The results revealed significant improvements in all the parameters measured. Voluntary intake increased significantly ($P<0.05$) in rams fed UTGNS and ULGNS based diets and was lower ($p<0.05$) in the UGNS group. The *in situ* rumen degradation characteristics of both the GNS test materials and the GNS based diets DM were determined. While DM disappearance was higher ($P<0.05$) in UTGNS based diets, its DM degradability was lower ($P<0.05$) than the other treatments. The UTGNS based diets had lower ($p<0.05$) DM degradability than the treated group while the ULGNS based ration was improved compared to other treatments. DMD indicated an increase in the ULGNS based diet. On the other hand, LGNS based diet group had the best ($P<0.05$) nitrogen retention as compared to other treatments. The overall results suggests that treatment with urea and lime on GNS increased the CP content by 100%, improved take by 5.7g/day, increased DMD by 7.4% and increased the DM disappearance at all incubation periods in Yankasa rams.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

ADF: acid detergent fibre

CP: crude protein

DM: dry matter

ED: effective degradability

EE: ether extract

GNS: groundnut shells

LAB: lactic acid bacteria

LGNS: lime treated groundnut shells

NDF: neutral detergent fibre

NFE: nitrogen free extract

UGNS: urea treated groundnut shells

ULGNS: urea-lime treated groundnut shells

UTGNS: untreated groundnut shells

CHAPTER ONE

1.0 INTRODUCTION

Feed scarcity is one of the major constraints to livestock production in the West African Sub-region (Glatzle, 1992). There is shortage of the conventional animal feed because food grains are required almost exclusively for human consumption. Poor quality roughages comprise a huge part of the feed available to ruminants for a considerable part of the year (Preston and Leng, 1987). The poor quality of the feed resources available to ruminants results in low plane of nutrition (Doma *et al.,* 1999) with attendant low productivity of our indigenous animals (Otaru *et al.,* 2011).

Small ruminants play a key role in bridging the wide gap between requirement and supply of animal protein for human consumption (Osinowo *et al.,* 1991) because of their special features such as relatively short generation interval (compared to cattle), high reproductive rate and low production cost. Given the estimated population of 34.5 million goats and 22.1 million sheep in Nigeria (Abdu *et al.,* 2012), the importance and advantages of small ruminants cannot be over looked.

The main feed resources for ruminant animals are pastures, crop residues and other agro-industrial by-products. In the dry season and post-harvest periods, these feed resources become the main sources of energy for ruminants when poor quality forages prevail (Kibon and Ørskov, 1993). The quantity and quality of available feedstuffs are major factors influencing productivity of ruminants in many parts of the world, especially regions with high population of livestock. Ruminants in such areas depend largely on crop residues during the long dry periods of the year for maintenance as well as for the production of meat, milk, skin and fibre. However, animal performance with such feedstuffs can be poor due to low voluntary intake and digestibility, which result from low protein concentrations and high levels of indigestible or slowly degradable fibre (Abdel Hameed *et al.,* 2013)

In Nigeria, there are plenty of groundnut shells (GNS): with an average of 1018 kg/ha produced annually (Larbi *et al.,* 1999). With the exception of a little quantity used as fuel and roughage, most of them are thrown away as waste. It is a common practice in Nigeria either to burn or leave them on the farm to rot. Burning has received global condemnation in the recent past and therefore the need for its conversion to a feed resource (Akinfemi, 2010). In recent times, many studies are being made on the comprehensive development and utilization of groundnut shells, and have obtained enormous development with prospective economic benefits, (Squidoo, 2014).

Feeding value of low quality fibrous feeds can be improved through various biological, physical, and chemical treatments. Among various chemicals employed for upgrading fibrous feeds is the use of alkali proved to be better (Khan *et al.,* 2006).

In parts of the world (especially in Africa) where small farms predominate, treatment with a urea solution followed by a period of storage under ensiled conditions may be more convenient. Treatment of crop residues with urea has three primary interrelated benefits, namely increased nitrogen concentration, feed intake and nutrient digestibility (Abdel Hameed *et al.,* 2013). However, ammoniation alone is insufficient to support ruminants beyond the maintenance level, thus there is a need for true protein supplementation of treated low quality forage based diets (Orden *et al.,* 2000). Supplementation is expected to correct any imbalances in the nutrients presented for metabolism (Russell, 2002). It is well established that ruminants fed low nitrogen (N) roughages also respond well to a N sources of plant or animal origin through supplementation (Abdel Hameed *et al.,* 2013; Preston and Leng, 1987). Supplementing low quality forage-based diets with N sources elevates ruminal ammonia N concentration to provide rumen bacteria with their requirements such as pH (near neutral); optimum temperature etc. to achieve maximum rates of fermentation (Abdel Hameed *et al.,* 2013).

Improving fibre utilization following treatment with alkalis (Sarnklong *et al.,* 2010) suggests that scope exists to derive more nutrients from fibre by microbial fermentation in the rumen. However, potentially degradable fibre may be transported from the rumen before fermentation could be complete. The extent of fermentation in the available time depends on the number of cellulolytic bacteria (Zulkarnaini *et al.,* 2012). Treated groundnut shells for feeding livestock will provide cheap and readily available feed resource among rural communities where groundnut production is predominant, while making the environment better by removing the “waste”.

1.1 Justification of the study

Aregheore (2000) points out that shortage of feed resources often impose major constraints on the development of animal production in the tropics and sub-tropics. Considerable quantities of crop residues are generated every year in most developing countries and their use in animal feeding is a common practice in tropical countries, especially Nigeria (Akinfemi *et al.,* 2012). The problem of dry season feeding of livestock in particular, has directed research efforts towards harnessing and enhancing the utilization of abundant arable by-products and crop residues as described by Malau-Aduli *et al.* (2003). Therefore, the concept of matching ruminant livestock production with available feed resources (Aregheore, 2000) has consequently intensified research into evaluation of more crop residues for use as livestock feeds in Nigeria.

Groundnut shell (GNS) contains more than 60% fibre, and therefore, has low digestibility (Singh and Diwakar, 1993). Groundnut shell, being fibrous in nature requires that its quality be improved for effective utilization by livestock (Fadel Elseed, 2005). Even though, highly developed reliable laboratory techniques/procedures such as acid detergent fibre and Menke *in vitro* gas production technique [$Y = b\ (1 - e^{-1})$] have been used to predict the nutritive values of groundnut shell to the animal, the techniques have often simply attempted to mimic the *in vivo* processes which is yet to be verified. Therefore, the present study intends to use the *in sacco* procedure to validate the use of GNS in the diets of small ruminants in Nigeria, which has the advantage of giving a very rapid estimate of the rate and extent of step-by-step degradation in the functioning rumen (Ørskov *et al.,* 1980).

1.2 Objectives of the study

The specific objectives of the study were:

1. To determine the efficacy of treatment with urea and lime on the nutritive value of groundnut shell.
2. To determine the voluntary intake, digestibility and nitrogen balance of urea and lime treated groundnut shell by Yankasa rams.
3. To evaluate the rumen degradation characteristics of urea and lime treated groundnut shell and groundnut shell based diets in the rumen of Yankasa rams.

1.3 Hypothesis

H_{o1}: Chemical treatment of groundnut shell has no effect on its nutritional value.

H_{a1}: Chemical treatment of groundnut shell has effect on its nutritional value.

H_{o2}: There is no difference in rumen degradation characteristics of Yankasa rams fed urea and lime treated groundnut shell and groundnut shell based diets.

H_{o2}: There is difference in rumen degradation characteristics of Yankasa rams fed urea and lime treated groundnut shell and groundnut shell based diets.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Contribution of Livestock to Socio-Economic Development

Livestock is an important component of Agricultural production system. In the African production system, there is hardly any farmer who does not keep one form of livestock or the other in addition to his crop production. This practice, which has made peasant farming to be described as mixed farming, developed from the need to reduce the risk associated with crop farming (Ahmed, 2002). Among all the livestock that make up the farm animals in Nigeria, ruminants, comprising sheep, goats and cattle, constitute the farm animals largely reared by farm families in the country's agricultural system (Lawal-Adebowale, 2012).

The population of small ruminants in Nigeria represent about 63.7% of total grazing domestic livestock which are widely distributed in rural, urban and peri-urban areas (Gefu, 2002). In Nigeria, there are estimated national population of 22.1 million sheep and 34.5 million goats (Ajala *et al.*, 2008; Lawal-Adebowale, 2012). The larger proportion of these animals' population are however largely concentrated in the northern region of the country than the southern region. Specifically, about 90 percent of the country's cattle population and 70 percent of the sheep and goat populations are concentrated in northern region of the country. Concentration of Nigeria's livestock-base in the northern region is most likely to have been influenced by the ecological condition of the region, which is characterised by low rainfall duration, lighter sandy soils and longer dry season (Lawal-Adebowale, 2012).

Small ruminants are a major source of livelihood in many areas of Nigeria. Unlike cattle, they are owned even by poorer segments of the community. Therefore, attempts to increase the productivity of small ruminants are an important route to improving the standard of living of the rural poor and peasants (Jokthan, 2014). The indigenous breeds of sheep in Nigeria, in order of importance are Yankasa (60%), West African Dwarf (20%), Uda (10%) and Balami (10%). Although, these figures have not changed significantly, it suggest the relative importance of Small ruminants in Nigeria (Ajala *et al.*, 2008).

Logbaby (2013) suggests that the increase in demands for livestock products resulting from rapidly growing economies, population growth and changing patterns of food consumption are creating opportunities to reduce poverty through livestock production and marketing.

2.2 Constraints Limiting Livestock Production in Nigeria

Some of the factors militating against livestock production in Nigeria are as follows:

2.2.1 Nutrition and feed supplies: The lack of feed that is adequate both in quality and quantity and accessible to animals all year round is the most outstanding problem of livestock production in Nigeria. The state of poor nutritive feed quality often lasts longer during the year than the period of forage abundance and high nutritive quality (Aribido, 2011). Supplementation with crop residues from cropped farmlands scarcely meets the requirements for animal growth. The unavailability of grazing feedstuff after harvest is aggravated by the widespread bushfire and imbalance between the stocking rate and carrying capacity of the range pose a great danger for the ruminants (Aribido, 2011; Iro, 2012).

2.2.2 Inadequate breeding programme: The consequence of the proliferation of local breeds of small ruminants in their numbers not responding to improvement in quantitative traits is as a result of haphazard breeding programme planned to improve our indigenous species through crossbreeding with exotic species which have failed in recent years (Oni, 2002; Aribido, 2011; Ago, 2013). It is still not clear as to categorically classify local breeds to be for meat or milk (Oni, 2002). They all exhibit dual or triple-purpose traits, with productivity far below the average expected (Aribido, 2011).

2.2.3 Pest and disease: Due to tropical nature of the Nigerian environment, a number of important epizootic diseases of livestock easily thrive (Aribido, 2011). Recent studies on the prevalence and seasonality of disease of ruminants indicated that helminthosis, ectoparasites, pneumonia-enteritis complex, pest de petits ruminants (PPR), and foot-rot were the major causes of mortality in sheep and goats under traditional agropastorial management in Northern and Southern Nigeria (Mohammed, 2002). However, other diseases of less epizootic nature are assuming increasing significance e.g. mastitis, brucellosis etc. These diseases are so virulent that they limit production, increase morbidity and cause widespread death of animals (Ago, 2013; Jokthan, 2014).

2.2.4 Land ownership and management: Land tenure remains a major obstacle to livestock development, for herders have no secured individual accesses or rights to land. Communities and individuals who crop the land often lay claim to ownership of the land. A concession to carry out agricultural activities is merely given to settled pastoralists rather than permanent land tenureship. Little or no opportunity is available for pastoralists to invest and develop the land for a full return of benefits and expansion (Aribido, 2011).

2.2.5 Low investment potential: The slow rate of growth of the livestock industry in Nigeria denotes a long gestation period for investment to mature. This is contrary to quick return on investment desired by financial institutions like banks and investment houses. Livestock projects are scarcely attractive which makes collaterals and guarantee of substantial value not easily available for livestock producers to secure sufficient loans to improve production even in few instances where financial institution may be willing to do so (Aribido, 2011; Ago, 2013).

2.2.6 Institutional problems and policies: Lack of genuine institutional support and political will to muster required efforts to improve livestock production cannot be overlooked as part of the problems confronting the industry (Devendra and McLeroy, 1982). Countries such as India, Netherlands, Australia, New Zealand etc. deliberately took on action-packed programmes which are outlined and implemented with very strong extension component that enables experts work in collaboration with native producers to find solutions to the problems of production (Aribido, 2011; Ago, 2013; Logbaby, 2013). In Nigeria, such planned programmes are tested within a limited area and frustrated by undue rivalry and competition for position, profession or financial benefits as well as poor implementation strategy (Aribido, 2011).

2.3 Feed Resources for Small Ruminants

Feeding animals is aimed at meeting the nutritional requirements for maintenance and production and these requirements vary depending on the species, age and size, stage of development and stage of production. The quantity of feeds voluntarily taken to meet the nutritional requirements depends on the palatability, digestibility and nutrients density of the feeds (Lakpini, 2002). A high efficiency of production demands attention to the feed resources in terms of their availability, quality, suitability for feeding and utilization (Devendra and McLeroy, 1982). For optimum livestock productivity, the available feed resource should match the number of animals in a given area (Assefa *et al.*, 2013). However, there is scarcity of information regarding the assessment of feed resources in semi-arid and arid zones of Nigeria.

Feed resources can be classified into the following, according to Marghazani *et al.*, (2014) as thus: rangeland/pastures, fodders, crop residues, and industrial by-products.

2.3.1 Rangeland/pasture

These are the natural pasture land filled with grasses and similar plants suitable for feeding animals (Kallah, 2004) which forms the major feed resources for natural grazing (Jayasuriya, 2002) in most developing countries. Nigeria has a total land area of about 923,770 km^2 (92.4 million ha) with an estimated stocking density of sheep and goats of 251 and 424 million head per km^2, respectively (Kallah, 2004). The Federal Ministry of Environment in Nigeria estimate the range land to be 9570 km^2 with arable land about 35%; 15% pasture; 10% forest reserve; 10% for settlements and the remaining 30% considered uncultivable for one reason or the other (Aregheore, 2009).

Therefore, the productivity and efficiency of livestock production depend on the ability of the range environment to supply forage in meeting the nutritional needs of animals for maintenance, growth and reproduction (Devendra and McLeroy, 1982).

In the past few years, a rapidly expanding human population has markedly increased pressure on land, causing arable land to encroach on the best of the grazing land (Ibrahim, 1998; Lemus and Brown, 2008). Meanwhile, these areas subjected to long dry seasons, where insufficient plant biomass carried over from the wet season to support domestic livestock population tends to become more acute as the dry season becomes established (Rabbit, 2012), when protein content of the natural grazing falls, often from 12–14% to about 6–8%. The fall in crude protein content is also accompanied by an increase in fibre content. Thus, the animal is faced with insufficient amounts of a low quality and relatively indigestible feed. The situation is intensified by drought (Jayasuriya, 2002).

The feed resources in rangeland are the green herbaceous plants such as grass e.g. elephant grass or legume family e.g. *Calliandra calothyrsus* (Makkar, 2002b), broadleaf herbs (forbs) (Kallah, 2004), and herbaceous edible portions of shrubs and trees which can serve as additional seasonal feed (Hernández and Sánchez, 2014) and browse plants such as brush, shrubs, and vines with woody stems (Lemus and Brown, 2008) which can be either leguminous or non-leguminous (Amodu and Otaru, 2004).

2.3.2 Fodders

This is also one of the main source of livestock feeding (Marghazani *et al.,* 2014). They can be used as hay, soilage and silage. They have the potential for alleviating some of the feed shortages and nutritional deficiencies experienced in the dry season on smallholder farms (Simbaya, 2002b). Fodder crops are grown usually to feed sheep for fattening purposes, they are usually produced under irrigation and fed in green state as soilage without recourse to curing as hay or silage (Devendra and McLeroy, 1982).

Nigeria has a wide range of shrub and grass species that can be used as fodder for ruminants. Some examples of these species are *Acacia albida*, *A. nilotica*, *A. senegal*, *Tamarindus indica*, *Balanites aegyptiaca*, *Ficus platyphylla*, *Ziziphus mauritiana*, *Leucaena leucocephala*, *Gliricidia sepium*, *Cajanus cajan*, *Stylosanthes guianensis*, *Gmelina arborea*, *Panicum maximum*, *Bauhinia rufescens*, *Moringa oleifera* etc. (Amodu and Otaru, 2004)

Leucaena leucocephala foliage is noted for its very high nutritive value for ruminant production. It has an edible fraction with 55-70% digestibility, 3-4.5% nitrogen, 0.8-1.9% calcium and 0.23-0.27% phosphorus (Hernández and Sánchez, 2014). *Gliricidia sepium* is normally used as protein supplement to low quality tropical forages for cattle, sheep and goats. It has a crude protein level of 18–30% and in vitro digestibility of 60–65%. Increases in live weight gains of approximately 25% have been reported for steers grazing Gliricidia-grass pastures in the Caribbean, compared with steers grazing grass alone. Results from experiments with dairy cows and buffaloes in the Caribbean reported similar or slightly increased milk yield and milk fat yield when concentrates were replaced by Gliricidia forage up to 25% of intake (Hernández and Sánchez, 2014). *Moringa oleifera* has an edible fraction with 57–79 digestibilities, 17–23% crude protein, 2.64% calcium and 0.23% phosphorus. Fresh biomass improves feed intake and animal performance in cattle, sheep, and goats as supplement in basal diet of grasses (Price, 2007). The nutritive value of *Stylosanthes guianensis* is 12–20% crude protein, 52–60 % *in vitro* digestibility, 0.2–0.6% phosphorus and 0.6–1.6% calcium. Grazing cattle gain between 250–600 g/ha/day and 300–500 kg/ha/yr on *S. guianensis* in the Caribbean (Horne and Stür, 2001; Hernández and Sánchez, 2014).

2.3.3 Crop residues

Crop-residues are fibrous aftermath of farm crops after the harvest of the primary produce for human consumption (Jayasuriya, 2002; Simbaya, 2002a). This feed resource probably ranks as the second most important feed resource for tropical ruminant population and provide the chief sources of basal feed for smallholder flocks during much of the dry season (Devendra and McLeroy, 1982; Smith, 1989).

Hostville (2013) estimated that over 111.5 million tons of crop residues are produced in Nigeria each year. Crop residues comprise a vast array of plant materials that vary in their origin as well as their physical and chemical nature. A variety of crop residues are available in Nigeria. Some are abundant and more useful, while others are available only in small quantities and, therefore, of secondary importance. Maize, rice and groundnuts are the major crops that yield large aftermath (Devendra & McLeroy, 1982), and the majority of residues are considered as a nuisance (Smith, 1989). A large quantity of crop residues is available in Nigeria for livestock feeding (Makkar, 2002b) with an estimated annual quantity of 3.2 million and 1.1 million tonnes for maize and rice, respectively (Smith, 1989) but only a small portion of that have been put into use by livestock farmers due to their low Nitrogen and high crude fibre contents which restricts intake and digestibility (Simbaya, 2002a; Smith, 2002b).

The bulk of the crop residues are simply burnt to clear the fields for the next cropping season while some are ploughed under as a way of recycling nutrients into the soil whereas some are simply left to rot in the fields (Simbaya, 2002a) especially in areas where land is prioritized for crop production (Assefa *et al.,* 2013).

Nutritive value of crop residues varies according to species, varieties, environmental conditions, stage of maturity and methods of harvest, storage and feeding among other factors (Smith, 1989; Hostville, 2013). The nutritive value can be determined by their chemical composition or by combination of chemical constituents and gas released on incubation of feeds in an in vitro or in vivo procedures (Aregheore, 2000).

The major constraint to using crop-residues as a feed resource is their high fibre content, which tends to limit intake and digestibility in animals (Smith, 2002b). Crop-residues are also associated with low protein and mineral contents, which cannot support adequate microbial growth or meet the host animal’s nutrient requirement for increased performance (Simbaya, 2002a). Animal performance with such feedstuffs can be poor due to low voluntary intake and digestibility, which result from low protein concentrations and high levels of indigestible or slowly degradable fibre (Abdel Hameed *et al.,* 2013). Other studies have proved that when poor quality crop residues such as maize stover is not treated chemically or otherwise prior to supplementation, response of animals' performance is poorly expressed (Ndemanisho *et al.,* 2007)

2.3.4 Industrial by-products

These are by-products derived from the processing of a crop or animal product, usually by an industrial concern (Devendra, 1990; Simbaya, 2002a). Included in this category of feed resources are molasses, bagasse, oilseed cakes, maize milling products, citrus pulp, and animal by-products including meat and bone meal, fish meal, etc. These materials are usually of very high nutritive value (low fibre-high protein feeds) and often too expensive for the traditional smallholder farmers (Jayasuriya, 2002). The ruminants are better able to utilize a wide range of such materials than the simple-stomached animals because of the activity of the microbes normally present in the fore-stomach of ruminants (Devendra and McLeroy, 1982)

The main limitation to increased use of such materials in rural areas is that they are usually produced in urban or peri-urban industrial areas. Thus, if these products are to be utilised by smallholder farmers, they have to be transported back to rural areas (Devendra and McLeroy, 1982; Simbaya, 2002a). These products are also in high demand by the commercial farmers, who are mostly located in peri-urban areas, thus having an advantage over small-scale farmers, not only in terms of purchasing power but also in transport costs. Due to the nature of these by-products, they often require special transportation and storage facilities (e.g. molasses) as stated by Simbaya (2002a).

2.3.5 Groundnut shells as feed resource for small ruminants

2.3.5.1 Production potential

A very important class of non-conventional feedstuff in Nigeria is groundnut shells. Groundnut (*Arachis hypogea*) is an important cash crop (Alu *et al.,* 2012) especially in the northern part of Nigeria where large tonnages of it is produced annually (Akinfemi, 2010). Groundnut shell is a waste produced when the nut is being processed for consumption by breaking the shell open manually or mechanically (Alu *et al.,* 2012); the pod or pericarp contains about 25–40% shell (Singh and Diwakar, 1993; Vyas *et al.,* 2005) of the total mass produced. From the production, processing and consumption of groundnut, there are a great variety of remains especially the husks, which create increasing problems of elimination (Akinfemi, 2010).

In Nigeria, from extraction rates of 1 kg seed to 3 kg of groundnut shells, the corresponding crop residue production has been estimated to be 1.3 million tonnes in the major production areas of Sokoto, Zamfara, Kano, Bauchi, Adamawa, Kaduna, Benue, Borno, Nasarawa and Anambra States of Nigeria (Hostville, 2013). Groundnut shells are used as mulch, bedding, fuel, building materials or source of organic fertilizer etc. (Vyas *et al.,* 2005; Akinfemi, 2010). It is abundantly available from October to May in the Northern region (Alu *et al.,* 2012) and can supply enough roughage for the ruminant population in the country if properly harnessed and processed (Hostville, 2013).

For now, groundnut shell could be very cheap because, being a waste, the only costs would be those of gathering, processing and transporting to points of use. Exploiting cheap feed resources for animal production would lower the market price of animal products and, therefore, increase the intake of animal protein by the general populace in developing countries, such as Nigeria (Akinfemi, 2010; Adamafio *et al.,* 2012).

2.3.5.2 Feed value of groundnut shells

From nutritional perspective, plant material is made up of two fractions – cell contents and cell walls. The cell contents, which are usually highly digestible, constitute only a small fraction of the dry matter of the groundnut shell, and hence make only a minor contribution to the feed value. The cell walls which make up the major fraction of groundnut shell may be poorly digestible, depending on the relative extent of its constituent parts: lignin, cellulose, hemicellulose, silica, and how they are linked with each other (Smith, 1989; Hostville, 2013).

In general, groundnut shells are characterized by low levels of one or more key nutrients which limit their utilization by livestock. They are inherently low in crude protein, readily fermentable energy (Rana, 1986; Hostville, 2013), essential minerals but contain high levels of structural carbohydrate or fibre (Abdel Hameed *et al.,* 2013). As a result the DM intakes

(DMI) are too low to permit digestibility; adequate nutrient intake for maintenance and production (Akinfemi, 2010); and the rate at which particles breakdown to a critical size small enough to leave the rumen, resulting in low level of performance (Hostville, 2013).

Previous studies have shown that the use of groundnut shell in diets of monogastrics proved useful. Alu *et al.*, (2012) reported inclusion of groundnut shell fortified with Methionine at 15% level in diets of rabbits produced weight gain equal to those of rabbits fed the control diet. Alu *et al.,* (2012) also uncovered that rabbits fed diet containing 30% groundnut shell without palm oil, gained weight similar to those fed on control diet. With addition of palm oil, Alu *et al.,* (2012) found that feed intake of rabbits was not affected up to 50% groundnut shell in the diet. In the same study, when rabbits were fed groundnut shell up to 40% in the diet, intake was not affected. In another study, there was a high average weight gain, feed conversion ratio and daily feed consumption rate for rats fed untreated groundnut shell compared to the rats that received treated groundnut shells (Adamafio *et al.* 2012).

Furthermore, Growing pigs fed on a diet containing 40% groundnut shell have been observed to perform satisfactorily (Alu *et al.,* 2012) and produced leaner carcasses which indicate economy of feed conversion. However, overall growth and feed efficiency from 18–80kg were not influenced by the level of groundnut shell. Alu *et al.* (2012) found no significant difference in average daily weight gain, feed conversion efficiency or carcass characteristics when groundnut shell replaced up to 54% of maize in diets of growing–finishing pigs. The inclusion of groundnut shell at 30% in the ration was observed to depress the growth of young pigs.

Groundnut shells contains more than 60% fibre, and therefore, has low digestibility (Singh and Diwakar, 1993). The nutritive value of groundnut shell depends not only on their digestibility, but also on the amount of intake by an animal. Generally, palatability, seasonal variation and availability are some factors that influence feed intake by an animal (Aregheore, 2000). The high cell wall content (Neutral Detergent Fibre) in the groundnut shells prevent enough consumption and makes rumination more difficult for younger animals while the high fibre content (Acid Detergent Fibre) limits its digestibility. The combination of the two above mentioned factors restrict adequate nutrient intake and digestibility for acceptable production levels without supplementary feeding (Hernández and Sánchez, 2014).

2.4 Methods of Improving Crop Residues for Livestock Feeding

The global climatic changes are increasing the feed shortages prevalent in the arid and semi-arid lands for most parts of the year. These periods are characterised by poor quality feeds that lead to low feed intakes and reduced animal performance (Ondiek *et al.,* 2013). The arid and semi-arid areas are home to a lot of small ruminants and their sustenance is reducing due to dependence on low productive natural pastures (Ondiek *et al.,* 2013) supporting 46–58% of pastoral households. Low feed supply both in terms of quality and quantity results in retarded reproductive and growth performance of animals (Teklu *et al.,* 2011).

The reason for the poor performance of livestock in developing countries is the seasonal inadequacy of feed, and its low quality. These deficiencies have rarely been corrected by conservation and, or, supplementation, often for lack of infrastructure, technical know-how, poor management, etc. In addition, many feed resources that could have a major impact on livestock production continue to be unused, undeveloped or poorly utilised. A critical factor in this regard has been the lack of proper understanding of the nutritional principles underlying their utilisation (Makkar, 2002b).

Much research attention has been devoted to feed problems and solutions and optimal feeding practices (Lenne and Wood, 2004; Lukuyu *et al.,* 2009) but there has been relatively little systematic consideration of the constraints smallholders face, the feeding strategies and coping mechanisms they use, and the ways scientific knowledge and indigenous technical knowledge can be combined to help the farmers improve livestock productivity and livelihoods (Lukuyu *et al.,* 2011).

The bulk of poor quality roughage (crop residues) which is available during the dry season can serve as a source of feed for ruminants if handled appropriately. If diets based on crop residues are to be efficient, the residues must be upgraded to improve the nutritive value. Three approaches are available for improving the intake and digestibility of fibrous residues. These are: appropriate supplementation with additional nitrogen, readily available energy and minerals; treatment of the residue to improve biodegradation; and a combination of treatment and supplementation (Smith, 1989).

2.4.1 Treatment methods of crop residues

The low protein and fibrous materials (crop residues and natural grazing) have a pivotal role in dry season feeding, and, therefore, a modest improvement (5–10%) in their feeding value would substantially reduce the effects of underfeeding on both survivability and production (Makkar, 2002b). Crop residues can be enriched by different processes some of which can be carried out by small (rural) farmers themselves.

The main treatments for improving the voluntary intake characteristics and nutritive value of crop residues and by-products are physical, chemical or biological, of which one or more can be applied (Makkar, 2002b; Hostville, 2013). The various treatment methods are briefly discussed below in terms of their mechanism of action, effectiveness and suitability.

2.4.1.1 Chemical treatment

Chemical treatment involves the use of sodium hydroxide, calcium hydroxide, potassium hydroxide, ammonium hydroxide, anhydrous ammonia, urea/ammonia, sodium carbonate, chlorine gas, sulphur dioxide acid and oxidising agents (Sarnklong *et al.,* 2010; Wanapat *et al.,* 2013). Chemical treatments appear to be the most practical for use on-farm, as no expensive machinery is required, the chemicals are relatively cheap and the procedures to use them are relatively simple. However, the chemicals themselves are not harmless and therefore, safety precautions are needed in their use (Sarnklong *et al.,* 2010).

2.4.1.1.1 Alkaline Treatment

The most commonly used alkaline agents are sodium hydroxide (NaOH), ammonia (NH_3), lime and urea (Sarnklong *et al.,* 2010). Alkali agents have been most widely investigated and practically accepted for application on farms (Smith, 2002b). Basically, these alkali agents can be absorbed into the cell wall and chemically break down the ester bonds between lignin and hemicellulose or cellulose, and physically make the structural fibres swollen (Sarnklong *et al.,* 2010; Hostville, 2013). These processes enable the rumen microorganisms to attack more easily the structural carbohydrates, enhancing degradability and palatability of the rice straw (Selim *et al.,* 2002).

2.4.1.1.1.1 NaOH treatment: NaOH (caustic soda) has so far been considered the most effective alkali for treating crop residues, but has also been shown to have limited acceptability in a growing economy like Nigeria. This is due to its high cost and corrosive nature (Hostville, 2013). Several NaOH treatment methods to improve the use of crop residues for ruminant feeding have been developed (Sarnklong *et al.,* 2010). The principal advantages of the different NaOH treatment methods are increased degradability and palatability of treated straw, compared to untreated straw (Smith, 1989). However, NaOH is not widely available as a resource for small-scale farmers and may be too expensive to use. In addition, the application of NaOH can be a cause of environmental pollution, resulting in a high content of sodium in the environment (Sarnklong *et al.,* 2010). However, the caustic ash of some crop residues have been found to be as effective as NaOH under limited experimentation (Hostville, 2013).

2.4.1.1.1.2 NH_3 treatment: Treatment of straw with anhydrous and aqueous ammonia, urea or other ammonia-releasing compounds has been widely reported to improve degradability (Selim *et al.,* 2002). The principle of ammonia treatment is supposed to be similar to that of NaOH treatment. Ammonia treatment not only increases the degradability of the straw, but also adds nitrogen (Wanapat *et al.,* 2013) and preserves the straw by inhibiting mould growth (Sarnklong *et al.,* 2010). Besides, improvement in degradability of structural carbohydrates, ammonia treatment is an effective means of reducing the amount of supplemental nitrogen, reducing the costs of purchasing protein-rich feedstuffs, and enhancing acceptability and voluntary intake of the treated straw by ruminants (Lardy and Anderson, 2009). Although comparative studies in improving the energy value of straw have shown that ammonia treatment is less efficient than NaOH (Sarnklong *et al.,* 2010), its use may be more profitable for farmers as the added ammonia serves as a source of nitrogen. In a study using sheep, Selim *et al.* (2004) fed treated rice straw packed in polyethylene bags for 4 weeks with gaseous ammonia (3g NH_3 per 100g dry matter) to sheep and found that ammonia treatment increased the N content in the rice straw, slightly decreased the NDF content, but increased the ADF content. So, ammonia treatment increases feed value by making the cell wall more available for the rumen microorganisms and also the increased N content improves microbial growth (Sarnklong *et al.,* 2010). However, ammonia treatment of crop residue has been reported not to be practicable in Nigeria and other developing countries with low technological base because of the unavailability of the forms (anhydrous and aqueous) of ammonia, and even if they are available, the high cost of transportation of gaseous ammonia in special gas tankers, and the highly technical personnel required to handle this potentially hazardous material do not make it safe and economically feasible (Hostville, 2013).

2.4.1.1.1.3 Urea treatment: A safer alternative to ammonia has been urea, which is available in most areas as fertilizer and precursor of ammonia. The use of urea as a precursor of ammonia has been recommended for developing countries for its simplicity and safety in application, availability in local markets at cheap prices and preservative properties (Abdel Hameed *et al.,* 2013; Hostville, 2013). Urea treatment is of most practical significance in the tropics, acting both as an alkali and a source of supplementary N to materials inherently low in crude protein (Simbaya, 2002a; Smith, 2002b). For practical use by farmers, urea is safer than using anhydrous or aqueous ammonia and also provides a source of nitrogen (crude protein) in which straw is deficient (Bheekhee *et al.,* 2002; Smith, 2002b). Since urea is a solid chemical, it is also easy to handle and transport (Sarnklong *et al.*, 2010) and it can be obtained easily in many developing countries. In addition, urea is considerably cheaper than NaOH or NH_3 (Makkar, 2002b). Wambui *et al.* (2006) reported that maize varieties with a low degradability responded better to urea treatments than higher quality stover, increasing the *in vitro* dry matter degradability. Urea treatment may therefore be most suitable for small-scale farmers to improve the quality of straws, particularly varieties showing a low degradability (Sarnklong *et al.*, 2010). Numerous investigations involving urea treatment of rice straw, with or without additional supplementation, have been performed both in the laboratory (Vadiveloo, 2003) and also in field trials (Wanapat *et al.*, 2013; Karimi *et al.,* 2014; Yulistiani *et al.*, 2015). Urea treatment is relatively easy to apply and is effective. However, its uptake at farm level has been slow. Cost is often cited as a reason for this (Smith, 2002a). Where straw is widely available and relatively cheap, there has been some success in improving the nutritional value by adding urea. This can improve the protein level significantly (e.g. 2–14%) but is likely to be low in energy and will require supplementation with grain or other high energy ration (DPI, 2007). Using urea is regarded as a practical and available method in livestock production, especially in developing countries, as it is relatively cheap, adds nitrogen to the ration and is relatively safe to work with (Sarnklong *et al.,* 2010).

2.4.1.1.1.4 Lime treatment: Lime ($CaO/Ca(OH)_2$) is a weak alkali agent with a low solubility in water. It has been reported that lime can be used to improve the utilization of straw and also can be used to supplement the ration with calcium, which has been found to be in a negative balance in sheep fed only wheat straw (Chaudhry, 2000). Soaking and ensiling are two methods of treating straw with lime. Although lime treatments increase the degradability of straw, the dry matter intake decreases, due to a reduced acceptability of the treated feed by animals (Smith, 1989; Sarnklong *et al.,* 2010). Sarnklong *et al.* (2010) reported that ensiling rice straw with 4 or 6% $Ca(OH)_2$ showed a higher in vitro dry matter digestibility than using 4 or 6% urea. However, mould growth was noticed in the $Ca(OH)_2$ treated straw. It was suggested that a combination of lime and urea would give better results than urea or lime alone. Additive effects of lime and the other alkali agents have been demonstrated (Trach *et al.,* 2001a) to add calcium to the diets. The use of lime may be safer and more cost effective to use than NaOH (Sarnklong *et al.,* 2010).

2.4.1.1.1.5 Urea-lime treatment: Such a mixture would be able to combine treatment effects on both chemicals together with the added calcium and nitrogen in the straw and thus increased digestibility. In such a combination either residual NH_3 or Ca would be necessarily as high as if the chemicals were used alone. In addition, since the amount of urea can be reduced at the expense of a cheaper chemical (lime), the mixture would be more economic, as long as the overall treatment effect is maintained or enhanced (Wanapat *et al.,* 2013). Sarnklong *et al.* (2010) showed that addition of $Ca(OH)_2$ to urea improved the in vitro dry matter digestibility. The authors demonstrated that a combination of 3% urea plus 4% lime at 50% moisture for 3 weeks incubation time was the most effective treatment for improving degradability of rice straw. Trach *et al.* (2001a) also found out that feeding cattle with 3% lime combined with 4% urea treated rice straw improved biological response for organic matter digestibility and average daily gain. However the combination of 3% lime and 2% urea can be biologically justified, at least as an alternative to 4% urea alone, for straw treatment.

2.4.1.1.2 Acid treatment

Acids that have been tested for their suitability to upgrade roughages are sulphuric acid, hydrochloric acid and chlorine (Smith, 1989), nitric and formic acid, orthophosphoric acid or propionic acids (Sarnklong *et al.,* 2010). The high cost, unavailability and the danger associated with the corrosive nature of acids makes it unsuitable for the average farmer (Hostville, 2013).

2.4.1.1.3 The use of organic solvents and oxidising agents to treat feed stuff

Extraction with organic solvents (acetone, methanol, ethanol) and treatment with oxidising agents (potassium dichromate, potassium permanganate and alkaline hydrogen peroxide) were very effective and removed/inactivated up to 90% of the tannins in oak leaves and up to 99% in agro-industrial and forestry by-products (Smith, 2002b). Others include Sulphur dioxide, Oxon, Chlorine and Chlorinated compounds (Smith, 1989). The use of oxidising agent holds promise for the large-scale detoxification of tannin-rich feedstuffs because of their low cost. These approaches are very simple, do not require complex equipment and are likely to be adopted by the feed industry in the future both in developing and developed countries. In addition, potassium permanganate can be made easily available in villages in developing countries (generally used for cleaning water in wells) and is noncorrosive (Smith, 1989). Hence farmers can use this chemical at home for detanninification of tannin-rich feedstuffs. The use of organic solvents for extraction of tannins has an advantage over oxidising agents because the solvents can be largely recycled and the tannins can be recovered for other industrial applications. The oxidising agents convert tannins to quinones, which are not capable of forming complexes with proteins under normal physiological conditions. However, the use of organic solvents is expected to be more expensive, unless the value of tannins recovered is higher than the cost of organic solvents used in the treatment (Smith, 2002a).

2.4.1.2 Physical treatment

In smallholder livestock systems most physical treatments of residues are either too expensive, the equipment is not available or its labour intensive. The methods involve in physical treatment are grinding, pelleting, boiling, steaming under pressure, gamma irradiation (Sarnklong *et al.,* 2010), wetting, chopping, ball milling, high pressure steaming (Smith, 1989) and ionization (Hostville, 2013).

Although wetting and soaking are simple procedures that small scale farmers can easily adopt, the benefits are not clear. Soaking and wetting crop residues is unlikely to improve their intake or digestibility. It might in fact result in reduced feed value because it causes substantial losses of soluble cell contents with a resultant decrease in digestibility (Smith, 1989).

Milling and grinding are the commonest methods adopted which are aimed at increasing the surface area available to enzymatic digestion of cellulose by rumen microorganisms and to increase the animal's voluntary intake. Reduction in particle size increases ease of handling, facilitates better storage, reduces wastage, reduces selective eating by animals and improves feed intake and digestion as relatively larger surface area becomes available for microbial activities (Hostville, 2013). It can be achieved by using a power driven chopper, a hand operated chaff cutter, a panga or a guillotine blade. There are other advantages, in that the surface area of non-lignin material exposed to microbial attack in the rumen is increased, thus increasing the rate of digestion, thereby reducing a possible limitation to intake (Smith, 2002b). The smaller the particle size the less scope there is for selection. Fine grinding (expensive and not common in practice) can reduce intake by increasing dustiness. Smith (2002b) found that chopping increased intake in sheep but not in cattle.

Chopping crop residues before feeding may reduce wastage and facilitate feeding. Since chopping does not alter cell wall structure, it generally does not improve digestibility, although (Smith, 1989) reported that lambs fed chopped groundnut haulms performed better than those fed long haulms in terms of intake, digestibility and growth. Intake of certain crop residues such as maize and sorghum stovers and rice straw may be improved by chopping, although there are reports that chopped and long rice straws are equally well consumed and digested by sheep (Smith, 1989). Nevertheless, chopping long crop residues to manageable lengths before feeding is recommended.

Grinding and pelleting are more severe physical treatments which reduce particle size. Reduction in particle size has the dual effect of increasing rate of passage and hence increasing intake, as well as increasing the cellulosic surface area exposed to microbial attack in the rumen, with the resultant increase in digestibility. Excessive reduction in particle size such as that achieved by ball milling or fine grinding may reduce digestibility because of increased rate of passage, although (Smith, 1989) pointed out that digestible dry matter may still be high under such circumstances. In spite of the reported positive beneficial effects of grinding by the usual methods on intake and digestibility, small scale farmers in the humid zone may not adopt the procedure because of economic considerations (Smith, 2002b).

High pressure steam treatment exerts both physical (separation of cell wall structures) and chemical effects (cleavage of cell wall constituent bonds, degradation of hemicellulose, formation of acids which hydrolyse other constituents) on crop residues. These processes may improve the digestibility of the treated materials and the net yield of available digestible dry matter (Smith, 1989). These improvements have not always been observed during *in vivo* evaluations. Negative effects on intake and digestibility have indeed been reported (Abdel Hameed *et al.,* 2013). Overtreatment is probably responsible for such negative results, as the optimum conditions of treatment for different residues have not been well defined. Such a costly, energy intensive and marginally effective treatment method cannot be recommended for our target users.

Gamma-irradiation according to Sarnklong *et al.,* (2010) may reduce resistance of fibrous residues to physical degradation without the necessity for fine grinding. Smith (1989) noted that irradiated rice straws had a shorter mean retention time in sheep than non-irradiated straw, suggesting that irradiation rendered the straw more susceptible to physical breakdown. Smith (1989) also reported that irradiation solubilises cellulose, hemicellulose and lignin in the cell wall. *In vivo* results, however, do not confirm these apparently beneficial effects, as the procedure has in general been shown to depress dry matter digestibility, and to have no effect on voluntary intake. The process obviously has no practical application for farmers in humid West Africa (Smith, 1989).

2.4.1.3 Physico-chemical treatment

The methods involve are particle size/chemicals, NaOH/pelleting, urea/pelleting, lime/pelleting, chemicals/steaming, etc. (Sarnklong *et al.,* 2010). There is evidence that combining physical treatments such as milling, grinding and steaming, which decrease particle size, with chemical treatments, increase the effectiveness of the chemicals, although the effects may not always be additive. In any case, such severe physico-chemical treatments may be out of reach of village farmers in humid West Africa (Smith, 1989).

2.4.1.4 Biological treatment

Biological treatment of crops residues is based on the use of certain microorganisms that are very efficient in lignin metabolism but with low degradation rates of cellulose and hemicelluloses; which include addition of enzymes, white rot fungi, mushrooms (Sarnklong *et al.,* 2010), yeast (Wambui *et al.,* 2010), composting and ensiling (Smith, 1989). Biological treatment is potentially safer and cheaper than chemical and physical treatment, but the process with unwanted microorganisms may be a disadvantage (Hostville, 2013). Biological treatment of crop residues need controlled conditions which are difficult to achieve at farmers level (Laconi and Jayanegara, 2015).

The use of fungi and/or their enzymes that metabolize lignocelluloses is a potential biological treatment to improve the nutritional value of straw by selective delignification, as mentioned in the review by Sarnklong *et al.* (2010). There are also a number of serious problems to consider and overcome. For example, the fungi may produce toxic substances (Sarnklong *et al.,* 2010). It is also difficult to control the optimal conditions for fungal growth, such as pH, temperature, pressure, O_2 and CO_2 concentration when treating the fodder. With recent developments in fermentation technology and alternative enzyme production system, the costs of these materials are expected to decline in the future. Hence, new commercial products could play important roles in future ruminant production systems (Beauchemin *et al.,* 2004).

Using ligninolytic fungi (*Sporotricum pulverulentum, Pleurotus ostreatus, Ceriporiopsis subvermispora, Cyathus steroreus* etc.), including their enzymes, may be one potential alternative to provide a more practical (Kholif *et al.,* 2014) and environmental-friendly approach for enhancing the nutritive value of rice straw and that of tannin-rich feed (Makkar, 2002a; Bhasker *et al.,* 2013). The cost of exogenous enzymes is at present too high to be applied by smallholder farms, but this may change in the future. Moreover, the application of ligninolytic fungi or their enzymes combined with chemical pre-treatments to rice straw may be an alternative way to shorten the period of the incubation times (Karimi *et al.,* 2014) and (or) decrease the amount of chemicals, effecting some synergy (Yang *et al.,* 2011). Certainly, since available data on treatments using fungi and their enzymes for improving the quality of rice straw are relatively scarce, these techniques should be developed further (Sarnklong *et al.,* 2010).

The use of yeast as a natural feed additive has been recognised as safe and can be used as a microbial protein source in ruminant diets, a probiotic to promote growth and activity of rumen microbes and a stabilizer of rumen fermentation status, hence preventing rumen flora and disturbances in ruminants. It can also increase viable bacterial cells, enhances ammonia utilization by ruminal microorganisms, increased microbial protein synthesis and can bind tannins or manipulate the rumen ecosystem and fermentation without posing any health risk to the animal, animal consumers and the environment (Wambui *et al.,* 2010).

Recent studies (Li *et al.,* 2010) have shown the improvement in feeding value of rice straw by ensiling. Some commercial lactic acid bacteria (LAB) have been developed to be used as additives in order to improve the quality of rice straw silage. The application of LAB (Chikuso-1) to whole crop rice could increase lactic acid and crude protein concentration and lower the pH value, butyric acid and ammonia nitrogen concentrations (Li *et al.,* 2010). In another study, Li *et al.* (2010) reported that *Lactobacillus plantarum* could lower the pH value and butyric acid concentrations, while increasing lactic acid, crude protein and acetic acid in rice straw silage. Inoculation of rice straw with LAB could also increase digestibility of DM and NDF and decrease NDF and ADF concentrations (Li *et al.,* 2010).

2.4.2 Supplementation

Chemical or other treatments of crop residues may improve their intake and digestibility, but unless adequate and appropriate supplementation is made to correct deficient nutrients much of the additional energy released will be inefficiently used (Rasambainarivo *et al.,* 2002). Smith (1989) have suggested that to optimize the utilization of crop residues, nutritional supplements should provide fermentable energy, fermentable nitrogen, micronutrients, by-pass protein, and by-pass energy to meet the requirements of both the microbes and host animal.

As rice straw is low in nitrogen and difficult to degrade, it is obvious that supplementation of a ration of rice straw with a protein source and a more fermentable energy source will improve the performance and production of the animals. Supplementation of a ration of rice straw with protein, energy and/or minerals may optimize rumen function, increase intake and thus maximize utilization of the rice straw (Sarnklong *et al.,* 2010).

The choice of supplement must tilt towards the more readily available and less costly alternatives (Smith, 2002b). Sarnklong *et al.* (2010) emphasized that it is primarily necessary to supply the rumen microorganisms with the nutritive elements needed for self-multiplication as well as for degradation of the cell walls of straw, leading to suitable conditions for maintenance of good cellulolysis. Different supplements can be used, such as concentrates, molasses, multi-nutrient blocks, green leaves, and locally available by-products.

2.4.3.1 Agro industrial by-products

Agro-industrial by-products result from the processing of agricultural produce such as oilseeds, sugarcane and citrus, and from slaughterhouses during the slaughter and processing of livestock. In comparison to crop residues, these products are very good in their

composition of useful nutrients and digestibility (Devendra, 1990; Yami, 2008). The feeding value of such by-products varies considerably. Agro-industrial by-products available for ruminant feeding include: milling by-products (bran and offal); oil seed cakes (palm kernel cake, cotton seed cake, soybean cake, groundnut cake, etc.); Sugar industry by-product (dried sludge, bagasse and molasses); brewery by-products (brewers' grain, distillers' grain); industrial by-product (indomie waste, tomato waste, fish meal, poultry waste, bakery waste etc.); non protein nitrogen (urea, purified amino acids, poultry litter and ammonium salts) (Ibrahim, 1998; DPI, 2007; Yami, 2008).
True protein especially with a low degradability, such as fishmeal or cottonseed meal, gave a larger response than those with a high degradability (Smith, 2002b), which includes NPN (Preston and Leng, 1987). However, the choice of which agro-industrial by-products to use depends on availability and cost (Ibrahim, 1998).

Oilseed cakes (oil meals) are by-products of processed oil crops: groundnut, sunflower and soybean. The cakes just like cottonseed cakes are rich in protein and fatty acids. They can be used alone or mixed with molasses for effective results. Research at ILRI (Osuji *et al.,* 1993) showed that sunflower cake was utilised effectively by Menz sheep in the Ethiopian highlands in terms of rumen microbial nitrogen synthesis, nitrogen retention and growth. The addition of small amounts of energy such as crushed maize grain increased microbial nitrogen synthesis, nitrogen retention and live weight gain (Ibrahim, 1998).

Although poultry litter is mainly used as a fertilizer, it has been shown to be a potential source of both nitrogen and energy for ruminants in providing low-cost feed components (Saleh *et al.,* 2002). The use of poultry waste in feeding ruminant livestock decreases the cost of feeding and also minimizes the effects of its contribution to environmental pollution in areas of intensive poultry production. More importantly, it solves partially the shortage of the animals' requirements for protein and/or energy during the dry season. Chemical composition and nutritive value of poultry litter have pointed out its potential use as an inexpensive nitrogen, energy and mineral supplement (Saleh *et al.,* 2002).

When beer is made, the residues are the spent grains and yeast. Sheep, goats and swine readily accept these as feed. Sources for these by-products are beer factories, which are increasing in sub-Saharan Africa, and local brewing points in several villages. The by-products from local brewers are richer in energy and protein than the residues from the factories (Ibrahim, 1998) and can be used to supplement animals in the dry season (Simbaya, 2002a).

Farmers mostly use molasses, a thick dark brown liquid which contains 50–65% sugar with little protein or water. It is thus a high energy feed. When added to cottonseed cakes, it increases the intake of coarse and less readily accepted cakes. It can be added to herbage during silage production. Molasses is an excellent feed provided it is supplemented with protein and minerals (Ibrahim, 1998).

2.4.3.2 Browse species

Browse plants are shrubs and trees whose leaves, twigs and woody parts can be eaten by animals. Examples of browse plants include *Leucaena leucocephala*, *Gliricidia sepium*, *Albizia lebbeck, Moringa oleifera* etc. Some of these browse shrubs are widely available and fed to animals by farmers in the tropics (Ndemanisho *et al.,* 2007). Goats are good browsers (Yami, 2008). More than 90% of the ruminant population survive exclusively on natural pasture. In advanced countries, pastures are usually augmented with preserved forage and concentrate (Ibrahim, 1998). Their use as supplements enhances intake of poor quality roughages, improve growth rates and increase reproductive efficiency in ruminants. The high dry matter degradability values of the leaf meals make them appropriate as supplements with basal diets of poor quality. The high dry matter degradability implies high fermentation and passage rates, thus allowing higher feed intakes by animals. In addition, this feature also facilitates faster release of nutrients to the microbial population in the rumen thus optimising microbial synthesis (Ndemanisho *et al.*, 2007).

Many of the above feed stuff can be harvested as dry feeds which could be classified as dry forage or roughages. The moisture content is usually between 50-85%. The dry matter nutritive value can vary depending on the stage of growth, or age of the plant, fertility of the soil etc. (Bawa, 2014). When compared with tropical grasses, browse is richer in protein and minerals in the dry season. The crude fibre content of browse also tends to be lower than that of grasses and usually ranges between 20 and 40% and is even lower in shoots and leaves. The low content of crude fibre suggests that the energy content of browse is higher than that of dry grass. Browse could, therefore, supplement the low protein content of grass forage during dry periods (Yami, 2008).

2.4.3.3 Mineral supplementation

At the level of productivity obtained under unimproved feeding systems in the small-scale farming setting, goats and sheep do not often show symptoms of mineral deficiencies or respond to mineral supplementation. Responses to mineral supplementation only occur after the major nutrient imbalances have been corrected (Yami, 2008). A feeding strategy based on treated and supplemented crop residues may correct these major nutrient deficiencies and improve productivity to such an extent that mineral requirements increase. Mineral supplementation may then become important, not only to avoid deficiency problems, but also to improve performance further (Smith, 1989).

Crop residue based diets are most likely to be deficient in sodium, copper and phosphorus. These are the same minerals found to be marginal or deficient in tropical grasses (Smith, 1989; Yami, 2008). Preston (1986) reported that most straws are deficient in the same three minerals in addition to sulphur, cobalt and calcium. The high concentrations of oxalates and silicates in some of the straws, such as rice straw, may further reduce the availability of calcium and magnesium, which are lost as silicates and oxalates in the urine and faeces.

Mineral supplementation can be done through the use of multi-nutrient blocks that contain the deficient minerals. Ideally, specially formulated mineral supplements are provided in the form of a mineral lick. Supplementation of common salt is widely practiced in many parts of Nigeria. Salt supplementation is especially useful in hot areas where sheep and goats lose large amounts of salt through perspiration. Goats obtain higher amounts of minerals because they consume more browse and consume a wider array of vegetation than sheep (Yami, 2008).

Very little work has been done in general in the area of ruminant mineral nutrition. It is possible therefore that goats and sheep fed mainly on well supplemented crop residues may become deficient in other minerals. There certainly will be a need for mineral supplementation studies to identify and correct the major mineral deficiencies likely to be associated with feeding strategies based on crop residues. Smith (1989) stated that routine provision of salt supplements to animals fed crop residues was necessary.

2.5 Effects of Chemical Treatment on Crop Residues

2.5.1 Performance of livestock

In the past years, several studies have been performed on chemical characterization and utilization of crop residues as ruminant feed (Sarnklong *et al.,* 2010; Yulistiani *et al.,* 2015). In addition, numerous methods of chemical treatments have been investigated, mixed along with other feed stuffs or components in order to improve the utilization of crop residues by ruminants (Trach *et al.,* 2001b; Abdel Hameed *et al.,* 2013). By treating crop residues with urea or calcium hydroxide or both along with true protein supplementation, intake, degradability and milk yield can be enhanced, compared to feeding untreated crop residues alone (Trach *et al.,* 2001b; Abdel Hameed *et al.,* 2013; Gunun *et al.,* 2013a, 2013b; Wanapat *et al.,* 2013). However, other workers (Distel *et al.,* 1994; Huyen *et al.,* 2012; Yulistiani *et al.,* 2015) suggested that treatment with urea did not increase intake. Melaku *et al.* (2004) and Smith (1989) reported that treatment improved intake and as a result increased weight gain and final body weight. The supplementation aids to support ruminants beyond maintenance level as treatment alone cannot correct the imbalances in the nutrients presented for metabolism (Abdel Hameed *et al.,* 2013).

Though, there are several reasons such as physical, socio-economic conditions and practical reasons for farmers not to apply the already developed methods of chemical treatments for improved utilization of straw, it has been accepted for application on farms (Sarnklong *et al.,* 2010). In general, the use of crop residues as an animal feed as well as its treatment with urea or calcium hydroxide is always an economic decision (Sarnklong *et al.,* 2010; Abdel Hameed *et al.,* 2013; Wanapat *et al.,* 2013; Yulistiani *et al.,* 2015) as it is relatively cheap and readily available.

2.5.2 Digestibility of livestock

Various chemicals have been used to improve the digestibility and utilization of low quality crop residues but the use of urea and or lime solution followed by a period of storage under air-tight conditions may be more practical (Abdel Hameed *et al.,* 2013). Some workers have shown that treatment of crop residues with urea improved organic matter digestibility, crude protein, NDF and ADF (Hossain *et al.,* 2010; Sarnklong *et al.,* 2010; Huyen *et al.,* 2012; Gunun *et al.,* 2013a, 2013b).

Other researchers have also reported that the treatment of crop residues with the combination of both urea and lime solution increased DMD, lignin, ADF, NDF, CP and NFE (Sahoo *et al.,* 2000; Trach *et al.,* 2001a, 2001b; Fadel Elseed *et al.,* 2003; Wanapat *et al.,* 2013; Yulistiani *et al.,* 2015). In the same vein, the treatment with urea-lime increased the *in vitro* and *in vivo* digestibility as reported by Pradhan *et al.* (1997) and Sarnklong *et al.* (2010)

2.5.3 Nitrogen balance of livestock

Leguminous crop residues are potentially good sources of crude protein for use in animal rations especially during the dry and drought season. But, they are high in lignin and the nutrient available in them cannot be accessed by the animals fed the roughage. Processing methods such as chemical treatment e.g. urea or lime treatment can make the nutrients accessible by the microorganisms in the rumen. Information on how processing methods influence the utilization of nitrogen in the crop residue and the rumen microbial protein production in sheep is limited. Such information when available will enable farmers to take informed decisions on appropriate processing method for groundnut shells as roughage source during the dry season (Mbewe *et al.,* 2014).

The concentration of N in the rumen is critical to bacterial growth when it is associated with energy sources and is directly related to the solubility of dietary protein and the N retention by the animal. Therefore, it is necessary to synchronise the ingestion of N and energy to optimize microbial protein synthesis and the reduction of excessive losses of N (Bastos *et al.,* 2014; Santos *et al.,* 2014). Mbewe *et al.* (2014) went further to state that nitrogen intake will be low when fed (velvet beans) as untreated and thereby lowers nitrogen utilization. In another study, urea-lime treatment ensures maximum utilization of nitrogen in soybean hulls thereby reducing nitrogen loss in urine and faeces (Bastos *et al.,* 2014). However, treatment with urea alone can lead to a high nitrogen loss in urine; due to the ammonia being converted from the NPN of the urea used in the treatment along with that produced in the liver (Santos *et al.,* 2014; Yulistiani *et al.,* 2015)

2.6 Feed Evaluation Methods

Previously, digestibility and chemical composition were used to describe the nutritive value of fibrous feeds (Makkar, 2002a). This proved inadequate because these attributes give little indication of the quantity of such feed an animal will eat and the quality of nutrients derived through digestion (Osuji *et al.,* 1993). Chemical composition of feeds and fodders determines their potential nutritive value (Ibrahim, 1998; Maheri-sis *et al.,* 2011) but it does not give the actual nutritive value of the feedstuffs until the nutrients lost in faeces, urine, gases, etc. from the animal during digestion, absorption and metabolism are also taken into consideration (Bawa, 2014). An understanding of the factors which affect rumen degradability of low-quality basal feeds and microbial protein production will assist scientists in designing diets that will be utilised more efficiently (Osuji *et al.*, 1993). In addition to determining responses from feeds, there is a need to establish causal relationships with a few methods to evaluate feed for animal performance.

2.6.1 Digestibility studies

Digestibility of a feedstuff is defined as that portion of feed or of any single nutrient of feed which is not recovered in faeces or in other words the portion which is acted upon by the microbes/digestive enzymes in the digestive tract and is absorbed by the system (Bawa, 2014). The digestibility of a feed determines the amount that is actually absorbed by an animal and therefore the availability of nutrients for growth, reproduction etc. Also the difference in energy value of feeds is due to their differing digestibility (Ibrahim, 1998). In a study, the apparent digestibility of dry matter, organic matter and crude protein was higher in urea treated rice straw than the untreated when fed to dairy steers (Gunun *et al.,* 2013a). The

CP digestibility might be due to the higher CP content in the urea treated rice straw and enhanced its intake. In the same study, the NDF and ADF digestibilities were also higher for the urea treated rice straw as a result of the swelling of the hemicelluloses-lignin complex in rice straw (Gunun *et al.,* 2013a) and makes it accessible for microbial digestion (Karimi *et al.,* 2014).

Chaudhry (1998) reported that lime improved the digestibility of wheat straw and supplement the ration with calcium when fed to sheep, though; it reduces the dry matter intake due to unacceptability of the treated feed by the animals. The combination of lime and urea was suggested to give better results than urea or lime alone (Sarnklong *et al.,* 2010). Pradhan *et al.* (1997) showed that the addition of lime to urea improved the dry matter digestibility of rice straw. This combination have the advantage of having an additive effect of increasing digestibility and increased the content of both calcium and nitrogen (Saadullah *et al.*, 1981).

Supplementation, however, is done to enhance intake and digestibilities of low quality roughage feed in the ration (Hostville, 2013). Adamu *et al.* (1995) observed that sorghum stover supplementation with cotton seed cake (CSC) resulted in an increased digestion of cellulose and hemicellulose when fed to sheep. They further concluded that supplementation had a marked effect on digestibility probably because the ruminal ammonia concentration required for maximum microbial biomass production has been met by the degradation of the supplement.

2.6.2 Rumen degradability of crop residues

2.6.2.1 Degradation

Treatments modify cell wall composition and increase *in sacco* rumen disappearance of crop residues, but the extent of increase depends on the type of chemical used (Chaudhry, 2000)

The degradability of rice straw showed higher degradation for the DM and NDF in the treated groups compared to the untreated (Karimi *et al.*, 2014) which indicate that the treatment was effective in making the cellulose available for the microbes. Chemical treatment (CaO, NaOH and alkaline H_2O_2) reduced NDF in wheat straw which enhanced its solubility and increased degradation than the untreated group (Chaudhry, 2000). Similarly, in another study, the DM disappearance of the treated rice straws (urea and poultry litter) was consistently higher than that of untreated straw which is as a result of the breakdown of the lignified structure of the cell wall constituents (Ngele *et al.*, 2009).

2.6.2.2 Degradation characteristics

Crop residues usually have a low potentially degradable DM fraction 'a+b' as measured by Ikhimioya *et al.* (2005) who evaluated the rumen degradability of various tree leaves and crop residues in which that of groundnut shell was found to be the lowest using the nylon bag technique in rams. Similarly, Chaudhry (2000) reported that untreated wheat straw had a lower degradation characteristics compared to other alkali treated group when fed to sheep. He stated that CaO could be used as an alternative for NaOH because it modified cell wall composition and increased rumen degradation *in sacco* of wheat straw which in turn increased straw digestion better than NaOH. In another study, Ngele *et al.* (2009) observed that rice straw treated with urea or poultry litter have higher values compared to the untreated group when fed to Bunaji bulls.

2.6.2.3 Effective degradability (ED)

In general, as degradability decreases, the fractional outflow rates increases. According to Preston (1986), the rate of degradation is an important parameter in the assessment of the fermentation of crop residues in the rumen. This is because; tropical crop residues have been reported to be of low feeding value (Ikhimioya *et al.*, 2005). They reported that crop residues, have low ED (k=0.05) for DM content despite high potential degradation, suggesting that they could have high fill values hence, low intake and animal productivity. In the same study, the ED values of crop residues had less than 50% evaluated at 2 and 3% outflow rates which show the confirmation of the generally low quality ascribed to crop residues (Ngele *et al.*, 2009).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of the Study

The study was carried out in the Teaching and Research Farm of the Department of Animal Science, Ahmadu Bello University (ABU), Zaria, located between latitude 11°04′N and longitude 7°42′E on an altitude of 706m above sea level (Wikipedia, 2015). The area falls within the Northern-Guinea Savannah zone of Nigeria, characterized by 6 to 7 months of rainfall varying from 0.0 to 816.0 (mm/month). The temperature ranges from 15.3°C in December and January to 36.25°C in March and April (World66, 2016).

3.2 Source and Processing of Groundnut Shells

The groundnut shells (SAMNUT 10 variety) used in this study were obtained from the Legume Research Programme of the Institute for Agricultural Research, ABU Samaru, Zaria. The shells were dried under a shade for 5 days and later pulverized using a hammer mill fitted with 1cm screen then stored in bags until when required for the study. The processed GNS were treated with urea at 5%, lime at 5% and urea–lime at 2.5% each, [i.e. 50g urea dissolved in 1 litre of water to treat 1kg of GNS; 50g lime dissolved in 1 litre of water to treat 1kg of GNS; and combination of 25g urea and 25g lime dissolved in 1 litre of water to treat 1kg of GNS, respectively]. The solution (urea, lime, urea/lime) was uniformly sprayed on the pulverized GNS and mixed thoroughly using a shovel on concrete floor (Can *et al.,* 2004). The treated GNS were stored in a sealed Perdue Improved Cowpea Storage (PICS) double polyethylene bags for a period of 21 days as described by Al-Masri and Guenther (1999). Thereafter, they were spread on polyethylene sheet to air dry awaiting the commencement of experiment.

3.3 Metabolism trial

Four intact Yankasa rams were used for this experiment. The experiment lasted for 15 days for each period. The animals were offered feed based on voluntary intake (5% of body weight) of the formulated diet throughout the experiment period. The first 10 days of the experiment was the adjustment period while day 11 to day 15 was the collection period.

The animals were weighed on the first day of the experiment and were placed in individual metabolic cages. Daily feed refused by each animal was collected and measured. On days 11 through 15 (5 days), the total faeces voided each day by each animal was collected in a bucket, weighed, mixed and a sample was taken for dry matter analysis. The dried sample (10% aliquot) was placed in a bag and saved pending chemical analysis. The urine was sampled using diluted sulphuric acid (0.1N H_2SO_4), added to the urine to ensure that the pH is less than 4 to avoid loss of nitrogen. The animals were weighed after faecal and urine collection, and before feeding on day 15.

Voluntary dry-matter intake and digestibility coefficient (McDonald *et al.,* 2010) of the feed was calculated as follows;

$$\text{Dry matter intake} = \text{dry matter offered daily} - \text{dry matter refused daily}$$

$$\text{DM Digestibility} = \left[\frac{nutreint\ consumed - nutrient\ in\ feaces}{nutrient\ consumed}\right] \times 100$$

3.4 Treatments and Experimental Design

Four concentrate diets containing 14% crude protein were formulated (Table 3.1). Other ingredients used in the complete diet included maize offal, cottonseed cake, bone meal and salt. The diets were offered to 4 rams in 4×4 Latin square design (Table 3.2) for the determination of intake, nutrient digestibility and N retention.

3.5 Experimental Animals and Housing

Four yearlings Yankasa rams weighing ±21kg were used for the digestibility studies at the Department of Animal Science, Teaching and Research Farm, ABU Zaria. The animals were purchased from the livestock market in Giwa LGA of Kaduna State. Their body were sprayed with Acaricide solution to protect against ectoparasites and de-wormed with Anthelmintic drugs (Albendazol) two weeks before the commencement of the trial. The animals were weighed using hanging balance to get their initial live weight, and were housed in metabolism cages (1.0×0.8m), elevated 0.8m above ground, with provision for separate collection of faeces and urine as described by Osuji *et al.* (1993). The metabolism cages were kept in a well-ventilated room with concrete cement floor.

3.6. *In situ* Rumen Degradation Characteristics of the untreated and treated GNS based diets.

The degradability study was carried out after the digestibility was done. Three rumen out of four that was used for the digestibility studies were taken to the Veterinary Teaching Hospital, Faculty of Veterinary Medicine, A.B.U. Zaria for surgery. After a month of observations and diagnosis, they were fistulated (fixed with cannula). After 2 weeks of adjustment period, they were taken back to the Department of Animal Science, Teaching and Research Farm, ABU Zaria for the degradability studies.

The fistulated rams weighing ±26kg were fed twice a day with a formulated diet having 14% CP (Table 3.3). They were housed in a pen, pegged separately with a considerable distance, on the floor. This is to avoid clash and rubbing their sides on the wall to prevent rupture of the stitched area. The cannula area was disinfected daily with Dettol and cotton wool to prevent infection, and sprayed with Charmil (multi-action skin spray) to repel insects and heal the wound. The material used as cannula was improvised, made from PVC plastic.

Incubation procedure

- The feed samples were ground through a 3 mm screen (mesh) using a Laboratory hammer mill.
- The samples were oven dried at 105℃ overnight to determine the dry matter (DM).
- The nylon bags (85) with size 5cm×10cm with pore size 41μm (ANKOM Technology) were oven dried at 65℃ for 30 minutes, allowed to cool and weighed.
- Three grams of the sample (both feed and test materials) was placed in the nylon bag, tied tightly using a nylon string which is resistant to the rumen microbes, at about 25cm to the cannula top. The nylon bag containing the sample was suspended in the rumen of the cannulated rams.

Samples were incubated at 0h, 12h, 24h, 48h, 72h and 96h for the untreated and treated groundnut shells while 0h, 3h, 6h, 12h, 24h, 36h and 48h are for the treated diets. Sequential removal approach (Osuji *et al.,* 1993) was used to withdraw the sample from the rumen.

After removal, the bags were washed thoroughly, under running water until the effluent was clear. The washed bags and samples residues were dried in an oven at 65℃ for 48 hours. They were allowed to cool in a desiccator and reweighed. The dry matter of the residue was determined just as that of the feed. The DM disappearance (Osuji *et al.*, 1993) was calculated using the formula:

$$\text{Disappearance of DM} = \frac{(\text{SWa} - \text{BW}) \times \text{DMa} - (\text{SWb} - \text{BW}) \times \text{DMb}}{(\text{SWa} - \text{BW}) \times \text{DMa}}$$

where:

SWa = weight of the sample + nylon bag before incubation

BW = weight of empty nylon bag

SWb = weight of the sample + nylon bag after incubation

DMa = dry matter of feed sample

DMb = dry matter of residue sample.

The rate of degradation and the effective degradability (ED) of DM were calculated with the formula as proposed by Ørskov and McDonald (1979).

$$Y = a + b\,(1 - e^{-ct})$$

$$\mathrm{ED} = a + [bc/(c + k)]\,(1 - e^{-(e+k)t})$$

where:

Y = degradability at time, t

a = intercept

b = potentially degradable fractions

c = rate of degradation of b

t = time

k = outflow rate of the rumen at 2, 4, 6, 8, 10 and 12%

Same procedure was done for the test materials separately.

3.7 Chemical Analysis

Samples of formulated feed, untreated and treated groundnut shells and faeces were collected, oven dried for proximate composition determination as described by AOAC (2005).

3.7.1 Dry Matter

Dry matter of the feed sample was determined by weighing an empty Petri dish and then weighing 10g of the feed sample into the Petri dish. The dishes and samples were placed in a hot air oven at 105^{o}C for 24 hours. The oven dried sample was weighed and dry matter content calculated as;

$$MC\ (\%) = \frac{\text{weight before oven dry (g)} - \text{weight after oven dry (g)}}{\text{weight of sample used (g)}} \times 100$$

DM (%) = 100 – MC

Where MC = moisture content

DM = dry matter

3.7.2 Ash

One gram of the dry matter sample was weighed into a previously weighed crucible and then it was completely combusted in a muffle furnace maintained at 550°C until a white ash was noticed inside the crucible after about 3 hours. The crucible was cooled in a desiccator and reweighed.

$$Ash\ (\%) = \frac{\text{(weight after ashing)} - \text{(weight of empty crucible)}}{\text{weight of sample used}} \times 100$$

3.7.3 Crude Protein

Kjeldahl nitrogen method was used for the protein determination. The processes involved are digestion, distillation and titration.

3.7.3.1 Digestion

One digestion tablet was added to each digestion tube with sample to be analyzed. 20ml of concentrated sulphuric acid was added into the sample; the digestion tubes were placed standing inside the digestion block and fitted with the exhaust cap (manifold) one by one on the top of each digestion tube for maximum air flow. The digestion lasted for 3 hours. The digested sample was diluted with 80ml of distilled water.

3.7.3.2 Distillation

Twenty millilitre of boric acid was measured into the receiver flask. The receiver flask was placed on the platform of the distilling unit, 50ml of sodium hydroxide solution in a distilling flask and heated for 15 minutes. The receiver flask was removed for the next stage.

3.7.3.3 Titration

The content of the receiver flask was titrated using diluted hydrochloric acid. Burette reading was recorded and calculated as;

$$Protein\ (\%) = \frac{(\mathrm{A} - \mathrm{B})\ \mathrm{x\ N\ x\ 14.01\ x\ F}}{\mathrm{Mg\ of\ sample}} \times 100$$

Where A = ml of acid used for the titration

B = ml of acid used for the blank

N = normality of acid used for titration

F = protein factor (6.25)

3.7.4 Crude Fibre

Trichloro-acetic acid (TCA) method was used to determine crude fibre. Two grams of the sample was placed into a 500ml conical flask and 50ml of the reagent (TCA) was added to it. The conical flask and the content was placed in an electro thermal heating mantle and allowed to boil for 40 minutes (time was taken when the solution began to boil).

The solution was removed and filtered, washed, air dried and oven dried at 75°C. After oven drying, the filtrate, it was transferred into a muffle furnace at 500°C until a white ash appeared. The residue was allowed to cool and calculated as;

$$Fibre\ (\%) = \frac{\mathrm{wt\ before\ ashing - wt\ of\ empty\ crucible - wt\ of\ filter\ paper}}{\mathrm{Weight\ of\ sample\ used}}$$

$$Crude\ fibre\ = \%\, fibre - \%\, ash$$

3.7.5 Ether Extract

Ether extract of the sample was estimated by solvent extraction method. 1g of the sample was placed into a previously weighed aluminium cups, 40ml of the extraction solvent (petroleum spirit) was added and hasted for about 15 minutes. The sample was removed from the solvent while the aluminium cups was oven dried reweighed.

$$Ether\ extract = \frac{(\text{weight of cup } + \text{ fat}) - (\text{weight of empty cup})}{\text{weight of sample used}} \times 100$$

3.7.6 Nitrogen Free Extract (NFE)

NFE is calculated as thus;

$$NFE = 100 - (\%\,crude\ protein + \%\,crude\ fiber + \%\,ether\ extract + \%\,ash)$$

3.7.7 Metabolizable Energy

The metabolizable energy (ME) of the diets was estimated according to the formula of Kwari *et al.* (2014).

$$ME\ (kcal/kg) = (37 \times \%CP) + (81.1 \times \%EE) + (35.5 \times \%NFE)$$

Where CP = crude protein

EE = ether extract

NFE = nitrogen free extract

The cell wall constituent of the urea and lime treated groundnut shells only was determined using the methods of Georing and Van Soest (1970).

3.8 Statistical Analysis

The data on nutrient intake, degradability and digestibility studies were analysed using the Generalised Linear Models Procedure (PROC GLM) of (SAS, 2002) in a one-way analysis of variance. The effect of treatment was tested and significant differences between treatment means established by Duncan's Multiple Range Test. The statistical model used was:

$$\mathbf{Y_{ijk} = \boldsymbol{\mu} + P_i + R_j + T_k + e_{ijk}}$$

where:

Y_{ijk} = Effect of the i^{th} period of time on the j^{th} ram fed the k^{th} treatment

μ = Overall mean

P_i = Effect of the i^{th} period of time

R_j = Effect of the j^{th} ram

T_k = Effect of the k^{th} treatment

e_{ijk} = Random error

The rate of dry matter disappearance and effective degradability of dry matter was analysed using the NEWAY programme developed by the Rowett Research Institute (Ørskov and McDonald, 1979).

Table 3.1: Formulation of the groundnut shells based diet

Ingredients (kg)	**UTGNS**	**UGNS**	**LGNS**	**ULGNS**
Maize offal	35.65	46.3	44.9	50.55
Cotton seed cake	22.35	11.70	13.10	7.45
GNS	40.00	40.00	40.00	40.00
Bone meal	1.50	1.50	1.50	1.50
Salt	0.50	0.50	0.50	0.50
Total	100	100	100	100
Calculated analysis				
Energy ME, kcal/kg	1829	2332	2337	2442
Protein (%)	14.00	14.00	14.00	14.00
Crude fibre (%)	36.03	19.22	18.98	12.44
Calcium (%)	1.57	0.56	0.56	0.55
Phosphorus (%)	0.73	0.37	0.38	0.33
Cost/kg diet (₦)	2357.25	1984.50	2033.50	1835.75

UGNS: untreated groundnut shell, UTGNS: urea treated groundnut shell, LTGNS: lime treated groundnut shell, ULTGNS: urea-lime treated groundnut shell.

Table 3.2: Experimental layout for each GNS based complete diets

Period	Ram 1	Ram 2	Ram 3	Ram 4
1	T1	T2	T3	T4
2	T2	T3	T4	T1
3	T3	T4	T1	T2
4	T4	T1	T2	T3

Table 3.3: Diet fed to cannulated rams during degradation study

Ingredients	Amount (kg)
Cowpea husk	50.00
Maize bran	34.00
Cotton seed meal (undeli)	7.00
Poultry manure(deep litter)	7.00
Bone meal	1.50
Salt	0.50
Total	100.00
Calculated analysis	
Energy	1088
Protein	14.01
Crude fibre	23.39

CHAPTER FOUR

4.0 RESULTS

4.1 Chemical Analysis

The chemical composition of the test ingredients and the experimental diets used in the study are shown in Tables 4.1 and 4.2, respectively. The result shows that both the treated and untreated groundnut shell (GNS) had high dry matter (DM) content with a mean value of 91.64%. Untreated groundnut shell (UTGNS) had higher lignin, ADF (acid detergent fibre), NDF (neutral detergent fibre) and EE (ether extracts) values of 23.50%, 59.90%, 69.20%, 64.00% and 2.00%, respectively compared to the treated GNS. However, its CP level (6.90%) was lower when compared to the treated groundnut shells. Among the treated GNS, urea-lime treated groundnut shell (ULGNS) had the highest CP value (15.43%) while lime treated groundnut shell (LGNS) had the highest NFE and Ash levels of 53.62% and 8.44%, respectively.

The results of the chemical composition of the formulated groundnut shells based diets are presented in Table 4.2. There was an increased the levels of DM (94.13%), lignin (10.08%), CP (18.25%) and Ash (6.19%) in LGNS; ADF (30.08%), EE (4.78%) and NFE (67.9%) in ULGNS; and NDF (54.28%) and CF (64.00%) in UTGNS. However, UTGNS had the least lignin (8.78%), ADF (27.19%), CP (16.69%), EE (4.18%), Ash (4.52%) and NFE (66.2%). NDF contents was least in LGNS (49.87%) while ULGNS had the lowest CF value of 4.66% compared to the other treatment rations.

Table 4.1: Chemical composition of urea and lime treated groundnut shells

Parameters (%)	UTGNS	UGNS	LGNS	ULGNS
DM	91.00	91.97	91.15	92.44
Lignin	23.50	14.12	12.08	11.11
ADF	59.90	29.36	31.88	29.87
NDF	69.20	61.32	62.15	60.60
CP	6.90	12.06	11.38	15.43
EE	2.00	0.98	0.69	0.87
Ash	5.30	8.36	8.44	7.29
NFE	21.80	51.45	53.62	50.27

UTGNS: untreated groundnut shell, UGNS: urea treated groundnut shell, LGNS: lime treated groundnut shell, ULGNS: urea-lime treated groundnut shell, DM: dry matter, CP: crude protein, EE: ether extract, NDF: neutral detergent fiber, ADF: acid detergent fiber, NFE: nitrogen free extract

Table 4.2: Chemical composition of the groundnut shells based diets

Parameters (%)	UTGNS	UGNS	LGNS	ULGNS
DM	92.17	94.04	91.88	94.13
Lignin	8.78	8.88	10.08	9.32
ADF	27.19	29.82	29.44	30.08
NDF	54.28	50.88	49.87	52.22
CP	16.69	17.94	18.25	17.56
EE	4.18	4.56	4.19	4.78
Ash	4.52	4.87	6.19	5.10
NFE	66.20	65.24	66.45	67.90

UTGNS: untreated groundnut shell, UGNS: urea treated groundnut shell, LGNS: lime treated groundnut shell, ULGNS: urea-lime treated groundnut shell, DM: dry matter, CP: crude protein, EE: ether extract, NDF: neutral detergent fiber, ADF: acid detergent fiber, NFE: nitrogen free extract

4.2 Nutrient Intake Study

The effect of urea and lime treated groundnut shells (GNS) based diets on nutrient intake for Yankasa rams are presented in Table 4.3. There were significant differences ($P<0.05$) on all parameters. The results shows that the daily feed intake for treated and untreated GNS were significantly different ($P<0.05$) and it was highest in UTGNS (1110.90g), followed by ULGNS (1088.10g) and lowest in UGNS (914.30 g). Water intake for UTGNS treatment had the highest value (3019.50 ml) which was significantly higher ($P<0.05$) than the other treatments which were not significantly different from each other. Also, the results of dry matter intake is significantly ($P<0.05$) higher for treatment ULGNS (1024.2 g) and UTGNS (1023.9 g) compared to other treatments whereas the organic matter intake had higher significant values ($P<0.05$) for UTGNS (973.7 g) and ULGNS (968.8 g) compared to other treatments. The crude protein intake was similar values for all treatment except for UGNS (16.03 g) which was significantly lower compared to other treatments. The ADF intake was highest for ULGNS (327.3 g) compared to other treatments while NDF intake was highest for UTGNS (602.95 g) and significantly ($P<0.05$) lowest in LGNS (86.48 g) and UGNS (465.18 g).

4.3 Nutrient Digestibility Study

The apparent nutrient digestibility coefficients of the formulated rations are presented in Table 4.4. There were significant ($P<0.05$) differences in all the parameters analysed across treatments. Generally, rams fed ULGNS diet had highest values ($P<0.05$) for all parameters. There was no significant difference in CP digestibility between UTGNS, UGNS and LGNS

Table 4.3: Nutrient intake of Yankasa rams fed groundnut shell based diets

Parameters	UTGNS	UGNS	LGNS	ULGNS	SEM
Daily feed intake (g)	1,110.90^{a}	914.30^{b}	975.50^{b}	1,088.10^{a}	63.91
Water intake (l)	3,019.50^{a}	2,562.00^{b}	2,693.80^{b}	2,816.00^{b}	176.75
Dry matter intake (g)	1,023.90^{a}	859.80^{b}	896.30^{b}	1,024.20^{a}	59.22
Organic matter intake (g)	973.70^{a}	815.20^{b}	835.90^{b}	968.80^{a}	55.79
Crude protein intake (g)	185.40^{a}	164.03^{b}	178.03^{a}	191.10^{a}	11.22
Acid detergent fibre (g)	302.00^{b}	272.60^{b}	287.20^{b}	327.30^{a}	18.56
Neutral detergent fibre (g)	603.00^{a}	465.20^{c}	486.50^{c}	568.20^{b}	33.32

^{abc}: Means with different superscripts within a row are significantly different ($P<0.05$), UTGNS: untreated groundnut shell, UGNS: urea treated groundnut shell, LGNS: lime treated groundnut shell, ULGNS: urea-lime treated groundnut shell, SEM: standard error of means

Table 4.4: Nutrient digestibility in Yankasa rams fed GNS based diets

Parameters (%)	UTGNS	UGNS	LGNS	ULGNS	SEM
DMD	39.17^{b}	36.27^{c}	36.72^{c}	46.55^{a}	2.06
Lignin	36.99^{c}	33.40^{d}	44.36^{b}	49.79^{a}	3.05
ADF	55.31^{c}	54.41^{c}	58.60^{b}	62.31^{a}	1.79
NDF	47.18^{b}	39.74^{c}	39.69^{c}	51.50^{a}	2.38
CP	65.90^{b}	65.98^{b}	65.98^{b}	69.90^{a}	0.76
EE	84.60^{c}	86.20^{b}	85.66^{b}	87.25^{a}	0.75
NFE	25.57^{ab}	16.87^{b}	21.46^{ab}	34.65^{a}	2.59

^{abc}: Means with different superscripts within a row are significantly different ($P<0.05$), UGNS: untreated groundnut shell, UTGNS: urea treated groundnut shell, LTGNS: lime treated groundnut shell, ULTGNS: urea-lime treated groundnut shell, DM: dry matter, CP: crude protein, CF: crude fiber, EE: ether extract, NDF: neutral detergent fiber, ADF: acid detergent fiber, NFE: nitrogen free extract, SEM: Standard error of means

4.4 Nitrogen Utilisation

The utilization of nitrogen (N) in Yankasa rams fed the experimental diets is shown in Table 4.5. Daily N intake was significantly ($P<0.05$) higher for rams fed LGNS (2.92 g/d) compared to those fed other treatments with UTGNS having the least value (2.67 g/d). There was significant ($P<0.05$) treatment effect on urinary nitrogen with highest value obtained in rams fed UGNS which was not significantly different from UTGNS and LGNS and lowest value in rams fed ULGNS. The N retained from the ingested rations was highest ($P<0.05$) in rams fed LGNS (0.48 g/d) and lowest in rams fed UTGNS (0.27 g/d) compared to other treatments. Levels for N absorbed are significantly highest for LGNS diets and lowest with UTGNS compared to other treatments. No differences resulting from the inclusion of untreated and treated groundnut shell in complete ration were observed for the excretion of nitrogen through faeces ($P>0.05$) and total N loss across the treatments.

4.5 Degradation Characteristics

4.5.1 Degradation characteristics of the urea and lime treated groundnut shell

The degradation characteristics of DM of the urea and lime treated groundnut shell (GNS) differed significantly ($P<0.05$) in disappearance rates (Figure 1), degradable constants (Table 4.6) and effective degradability (Table 4.7) for the different incubation times. The dry matter disappearance (DMD) of UTGNS was consistently higher ($P<0.05$) than the treated GNS. DMD generally increased in all treatments with time, although, at 48h, 72h, and 92h there was no significant variation ($P>0.05$) between UGNS and LGNS.

The immediately soluble fraction ‘a’ ranged from 24.04% in UTGNS to 19.97% in ULGNS (Table 4.6). The insoluble but rumen degradable fraction ‘b’ was least in UGNS (1.24%) and highest in UTGNS (5.81%). The rate of rumen degradable fraction (b) per hour ‘c’ of the test materials was slowest in ULGNS (0.026) and fast in UTGNS (0.085). UTGNS was observed to contain the highest amount of potentially degradable DM ‘a+b’ with 29.85% while UGNS had the lowest with 23.08%.

Effective degradability (ED) of DM calculated at 2, 4, 6, 8, 10 and 12% outflow rates from the rumen showed UTGNS consistently had significantly ($P<0.05$) higher values while the least values were recorded in ULGNS (Table 4.7).

4.5.2 Degradation Characteristics of the GNS Based Diets

Ruminal dry matter (DM) disappearance, degradation constants and effective degradability of GNS based diets are presented in Figure 2, Table 4.8 and 4.9, respectively. There were significant ($P<0.05$) differences for all incubation times in all rations incubated. ULGNS had the highest values at all times except for 0h and 6h in which UTGNS had the highest for both. LGNS had the lowest value for 0h, 3h, 6h, and 12h while UTGNS had the lowest values for 24h, 36h and 48h.

Significant ($P<0.05$) differences exist amongst all treatments for the degradation characteristics of the GNS based diets. UTGNS had the highest value for ‘a’ and ‘c’, LGNS for ‘b’ and UGNS for ‘a+b’. The lowest values recorded for ‘a’ was with ULGNS, ‘b’ and ‘a+b’ with UTGNS and ‘c’ with LGNS.

The effective degradability (%) differed significantly ($P<0.05$) amongst the GNS based diets. ULGNS had the highest values for 2%, 4%, and 6% while UTGNS had highest for 8%, 10% and 12%. The least values obtained for the effective degradability was with UTGNS for 2% and LGNS for 4%, 6%, 8%, 10% and 12% (Table 4.9).

Table 4.5: Nitrogen balance in Yankasa rams fed groundnut shell based diets

Parameters (%)	UTGNS	UGNS	LGNS	ULGNS	SEM
Nitrogen intake	2.67^{d}	2.87^{b}	2.92^{a}	2.81^{c}	0.00
Faecal nitrogen	1.47	1.45	1.53	1.51	0.04
Urinary nitrogen	0.93^{ab}	1.00^{a}	0.92^{ab}	0.91^{b}	0.01
Total nitrogen loss	2.40	2.45	2.45	2.42	0.04
Nitrogen balance	0.27^{c}	0.42^{b}	0.48^{a}	0.39^{b}	0.04
N retained as % of intake	10.07^{c}	14.64^{b}	16.32^{a}	13.95^{b}	1.35

^{abcd}: Means with different superscripts within a row are significantly different ($P<0.05$), UTGNS: untreated groundnut shell, UGNS: urea treated groundnut shell, LGNS: lime treated groundnut shell, ULGNS: urea-lime treated groundnut shell, SEM: Standard error of means

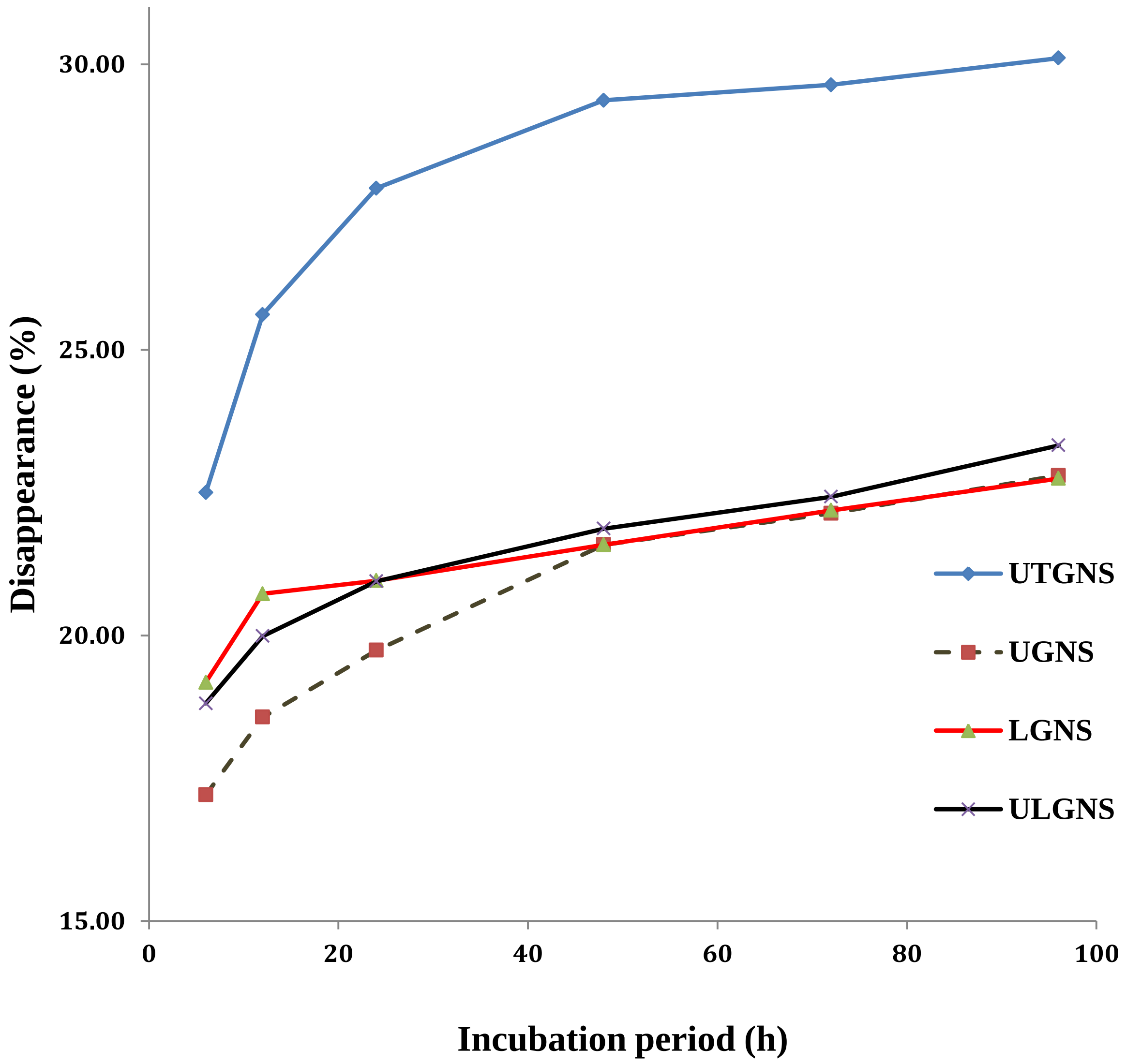

Figure 1: *In situ* dry matter disappearance (%) of the untreated and treated groundnut shells at different incubation time.

Table 4.6: Degradation constants of the differently treated groundnut shell at different incubation periods for the urea and lime treated groundnut shell

Parameters	Different treatments				SEM
	UTGNS	UGNS	LGNS	ULGNS	
a (%)	24.04^a	21.84^b	21.83^b	19.97^c	0.20
b (%)	5.81^a	1.24^c	3.70^b	4.07^b	0.49
a+b (%)	29.85^a	23.08^d	25.54^b	24.04^c	0.62
c (h^{-1})	0.085^a	0.038^b	0.036^b	0.026^c	0.01

^{abc}:Means with different superscripts within a row are significantly different ($P<0.05$), UTGNS: untreated groundnut shell, UGNS: urea treated groundnut shell, LGNS: lime treated groundnut shell, ULGNS: urea-lime treated groundnut shell, a: readily soluble fractions, b: insoluble fraction but degradable in rumen, c: rate of degradation of fraction b per hour, a+b: potentially degradable fraction, SEM: standard error of means

Table 4.7: Effective degradability of dry matter of urea and lime treated groundnut shell at different passage rate

Passage rates	Different treatments				SEM
	UTGNS	UGNS	LGNS	ULGNS	
k=0.02	27.90^{a}	22.13^{b}	22.20^{b}	21.53^{c}	0.16
k=0.04	26.73^{a}	21.97^{b}	22.00^{b}	20.77^{c}	0.20
k=0.06	25.97^{a}	21.87^{b}	21.90^{b}	20.43^{c}	0.21
k=0.08	25.40^{a}	21.87^{b}	21.87^{b}	20.30^{c}	0.22
k=0.10	25.10^{a}	21.83^{b}	21.87^{b}	20.17^{c}	0.22
k=0.12	24.87^{a}	21.83^{b}	21.83^{b}	20.10^{c}	0.22

^{abc}:Means with different superscripts within a row are significantly different ($P<0.05$), UTGNS: untreated groundnut shell, UGNS: urea treated groundnut shell, LGNS: lime treated groundnut shell, ULGNS: urea-lime treated groundnut shell, ED(k=0.02. 0.04, 0.06, 0.08) effective degradability calculated with outflow rates of 2, 4, 6, 8, 10 and 12%,SEM: standard error of means

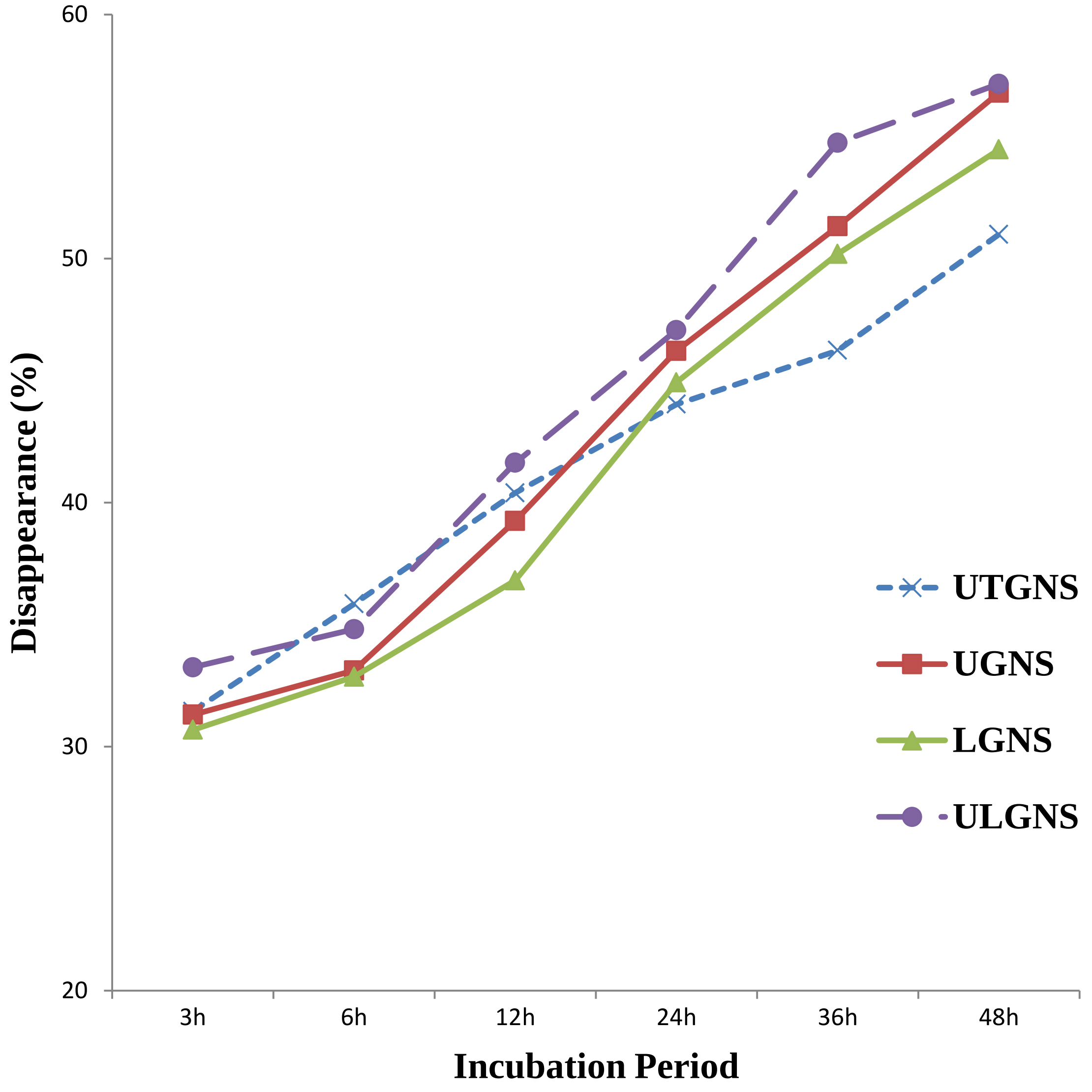

Figure 2: *In situ* dry matter disappearance of the groundnut shells based diets at different incubation time fed to the rams.

Table 4.8: Degradation constants of the differently treated groundnut shell based diets at different incubation periods for the groundnut shells based rations

Parameters	Different treatments				SEM
	UTGNS	UGNS	LGNS	ULGNS	
a (%)	40.40^{a}	38.47^{b}	36.11^{d}	37.17^{c}	0.27
b (%)	19.49^{c}	33.05^{a}	34.15^{a}	30.97^{b}	1.33
a + b (%)	59.89^{c}	71.52^{a}	70.26^{a}	68.14^{b}	1.57
c (h^{-1})	0.035^{a}	0.023^{c}	0.021^{c}	0.028^{b}	0.00

^{abc}:Means with different superscripts within a row are significantly different ($P<0.05$), UTGNS: untreated groundnut shell, UGNS: urea treated groundnut shell, LGNS: lime treated groundnut shell, ULGNS: urea-lime treated groundnut shell, a: readily soluble fractions, b: insoluble fraction but degradable in rumen, c: rate of degradation of fraction b per hour, a+b: potentially degradable fraction, SEM: standard error of means

Table 4.9: Effective degradability of dry matter of the differently treated groundnut shell based diets at different passage rate

Passage rates	Different treatments				SEM
	UTGNS	UGNS	LGNS	ULGNS	
k=0.02	47.67^{c}	51.97^{a}	50.27^{b}	52.40^{a}	0.49
k=0.04	44.10^{c}	45.70^{b}	43.93^{c}	46.40^{a}	0.41
k=0.06	42.47^{c}	42.80^{b}	40.97^{d}	43.37^{a}	0.33
k=0.08	41.63^{a}	41.20^{b}	39.30^{c}	41.57^{a}	0.27
k=0.10	41.20^{a}	40.30^{b}	38.37^{c}	40.37^{b}	0.24
k=0.12	40.90^{a}	39.70^{b}	37.70^{c}	39.57^{b}	0.21

^{abc}:Means with different superscripts within a row are significantly different ($P<0.05$), UTGNS: untreated groundnut shell, UGNS: urea treated groundnut shell, LGNS: lime treated groundnut shell, ULGNS: urea-lime treated groundnut shell, ED(k=0.02. 0.04, 0.06, 0.08) effective degradability calculated with outflow rates of 2, 4, 6, 8%,SEM: standard error of means

CHAPTER FIVE

5.0 DISCUSSION

5.1 Chemical Composition of Treated Groundnut Shells

The treatment of groundnut shell with urea (UGNS), lime (LGNS) and urea-lime (ULGNS) had no observable effects on percent ether extract. It had slightly affected the neutral detergent fibre composition of groundnut shell but increased the water-soluble non-structural carbohydrate sugar content, protein, acid detergent fibre, lignin and ash. As illustrated in the results, treatment with alkali (UGNS, LGNS, and ULGNS) resulted in a massive increase in the hydrolysis of cellulose. It may be inferred that the alkali treatment was effective in improving the hydrolysis of groundnut shell samples to release available nutrients encapsuled within the cell by the lignified cell wall. As reported by Chaudhry (200), Smith (2002a) and Adamafio *et al.* (2012) the immersion of maize stalks or wheat straw in alkali was found to be highly effective in improving degradability of the cellulose fraction of crop residues *in vitro.*

5.2 Feed and Nutrient Intake in Yankasa Rams

The findings under this investigation revealed the highly significant difference in improvement on daily feed intake on rams fed ULGNS and UTGNS based rations compared to the other treatments. These results were consistent with those found by Wanapat *et al.,* (2013) who found that the treatment with urea-lime increased DM intake of lactating cows compared with untreated rice straw. Meanwhile, it is in contrast to Wanapat *et al.* (2013) who found that if rice straw was treated with urea-lime chemical, it could have the highest result among all treatments. This means the combination between urea and lime could have more effectiveness on intake of GNS in ruminants. The increase in intake for ULGNS based diets under the present experiment may thus be explained by virtue of increased degradability in the rumen and increase in outflow of shell cell wall into the abomasum as a result of alkali treatment as reported by Trach *et al.* (2001b) and Wanapat *et al.* (2013). This combination will give a better result than urea or lime alone and has the advantage of an increased degradability, also an increased content of both calcium and nitrogen (Pradhan *et al.,* 1997; Sarnklong *et al.,* 2010). Furthermore, there was increase in feed intake when lambs were fed treated groundnut shells compared to untreated groundnut shells as reported by Abdel Hameed *et al.,* (2013). In a different study, Gunun *et al.* (2013a, 2013b) reported results for increased DM intake for treated rice straw compared to untreated rice straw in dairy cows. The increase in daily feed intake may be as a result of the increased palatability of the diet due to supplementation with high fermentable carbohydrates and protein which improved the nutritive value of the feed (Smith, 1989; Melaku *et al.,* 2004). The increase might also be as a result of high water intake which in turn aids in more saliva production that buffer the rumen pH, softening the fibre, effective microbial activity in the rumen and enhanced fermentation.

On the other hand, treatment with urea alone had a negative outcome on intake in the present study recording the lowest intake. This is in contrast to some researchers (Sarnklong *et al.,* 2010; Abdel Hameed *et al.,* 2013; Wanapat *et al.,* 2013) who demonstrated that treatment with urea will improve intake. However, Yulistiani *et al.* (2015) reported that urea treated rice straw did not increase intake when fed to sheep. This finding is similar to the findings in the present study. This might be attributed to animal differences of feed acceptability (Huyen *et al.,* 2012). Furthermore, the limitation for the intake might be as a result of slow digestion (Distel *et al.,* 1994) or distension of the rumen wall (Grovum, 1988).

5.3 Chemical Composition of the Experimental Feeds

The level of inclusion of cotton seed cake boosted the level of protein in all the diets, with a mean value of 17.61% giving them a level higher than the recommended CP level of 15% by

NRC (2007), for optimum maintenance or production for sheep. The high value of NDF in UTGNS could be as a result of the lignified nature of GNS in the diet because it was not treated with alkali. Furthermore, UTGNS had lower levels of CP, EE, Ash, and NFE compared to other treatments. The increased levels for crude protein, lower values for crude fibre and high levels of soluble carbohydrates could be as a result of effective supplementation to the groundnut shell for efficient ingestion of crop residues (Smith, 1989).

5.4 Nutrient Digestibility in Yankasa Rams

Rams fed ULGNS based rations had a higher DM, lignin, ADF, NDF, CP, and NFE digestibility than those fed other ration. The increase in DM, ADF, NDF, CP digestibility of ULGNS treatment was consistent with the earlier findings of others researchers (Trach *et al.,* 2001b; Fadel Elseed *et al.*, 2003; Wanapat *et al.*, 2013). The increase in DM digestibility of GNS based diets may have been due to the effect of alkali agents, linkages between lignin and hemicellulose was broken, which resulted in increased feed surface area for microbial attack and the consequent digestion of fibre. Improvement in GNS apparent digestibility as a result of treatment with lime and urea combination have also been reported (Zaman and Owen, 1990; Sahoo *et al.*,2000). Since the rumen is the primary site for fibre digestion, the increase in apparent digestibility of the ULGNS diet was presumably due to increased rumen degradability which resulted from increased susceptibility of structural carbohydrates of GNS cell wall to rumen fermentation as well as more energy being made available for better growth of rumen microbes for fermentation (Wanapat *et al.*, 2013; Yulistiani *et al.,* 2015). The combination of urea and lime highly increased the intake and *in vivo* digestibility of straw as suggested by Pradhan *et al.* (1997) and Sarnklong *et al.* (2010). In this combination, lime acts as the main alkalinity enhancer and urea is a source of NH_3 for supply of nitrogen to rumen microbes and for mould inhibition (Trach *et al.,* 2001a).

The UGNS based rations had the least digestibility coefficients and this is in contrast to some workers (Hossain *et al.,* 2010; Sarnklong *et al.,* 2010; Huyen *et al.,* 2012; Gunun *et al.,* 2013a, 2013b) who indicated that urea treated rice straw increased OM, CP, NDF, ADF digestibility. Furthermore, Abdel Hameed *et al.* (2013) suggested that urea treatment of groundnut shell increased growth performance and utilization in lambs. Trach *et al.* (2001a) have shown no improvement in straw digestibility or microbial protein production in the rumen of beef cattle when the CP content of straw diet was increased to above 8–10% DM. The digestibility of a feed is influenced not only by its own composition but also by the composition of other feed consumed with it. When roughage and a concentrate are given in equal parts in a ration, the digestibility of the concentrate mixture might differ from what is expected (Gao *et al.,* 2015). The associative effect is usually negative for digestibility of mixed rations, as a result of rapid fermentation of starch to volatile fatty acids depressed the rumen pH to 6 or less. The low pH inhibits cellulytic microorganisms and fibre digestibility is depressed. This indicates that starch have a direct effect on cellulolysis (Yulistiani *et al.,* 2015).

5.5 Nitrogen Utilisation in Yankasa Rams

There was an increase in N intake among treated groups. This may be due to the nutrient composition of the groundnut shell which had been improved by urea and lime treatment. According to Wanapat *et al.,*(2013), N excretion and retention could reflect differences in N metabolism because N balance is the most important index of protein nutrition status in ruminants (Ørskov, 1999). The excretion of N in urine displayed a minimum value (0.91 g/d) with ULGNS based diet. The nutritional demands of ruminants highlight the synchronization between protein and dietary carbohydrates in the rumen to maximize microbial synthesis, thereby reducing nitrogen loss (Bastos *et al.,* 2014).

It was noted that the highest loss was found with the UGNS ration. This was probably due to the presence of large proportion of NPN from the urea used for treating the GNS, cotton seed cake used in the diet and the N produced in the liver during metabolism (Santos *et al.*, 2014). Retention of N is considered as the most common index of protein status of the ruminant and it is a good estimate of the quantity of N available for deposition in body tissues (Bastos *et al.*, 2014; Yulistiani *et al.*, 2015). Hence, the positive N balance observed in the present study indicated that all diets supplied a significant amount of N with higher protein available for use by rams when fed with LGNS rations. Also, the N retained as percentage of intake presented a significant value on the average of 13.75 g/d. Thus, the positive N retention noted in all the treatments indicates that there was less loss of protein or nitrogenous compounds during the experimental period, thereby confirming that the protein fraction in the diet was efficiently absorbed and utilized for tissue growth by the animal.

5.6 *In situ* Dry Matter Degradation

5.6.1 Disappearance and degradation characteristics of the urea and lime treated groundnut shells

5.6.1.1 Disappearance of DM

The highest DM disappearance for UTGNS might be attributed to the way the UTGNS was prepared and the pore size of the material used for the nylon bag. At incubation time 6–96h, UTGNS also had the highest degradable fraction compared to the treated GNS. Although, raw GNS was suggested to digest slower than treated GNS (Sarnklong *et al.*, 2010), it still proved to degradable faster from the results obtained in this study, compared to other treatment diets. This suggests that untreated GNS might be dusty and would easily escape from the bag in the rumen (Ngele *et al.*, 2009) or it was able to provide an adequate environment for the microbes to degrade the material compared to the treated GNS. This seems to be in conflict with the result of this study which showed that UTGNS had more lignin, NDF, ADF and less soluble carbohydrates compared to the treated GNS. This disappearance ratio is most likely explained by the partial escape of the sample material from the *in situ* bag. The current *in situ* findings is in contrast with the study by Nguyen *et al.* (2007) who fed soybean hulls to cattle. They suggested that supplying a fibrous feed stuff to the rumen environment with the diet would promote fibre-digesting bacteria. They also suggest that feeding fibrous material will enhance forage digestion through additive and associative effects in a more efficient way than other feed materials.

The result of this study disagrees with those of many workers who reported that chemical treatment of GNS improved degradability compared to the untreated (Orden *et al.,* 2000; Promkot and Wanapat, 2003; Sarnklong *et al.,* 2010; Migwi *et al.*, 2011). The lowest result obtained from UGNS might be suggesting that the material had the presence of NPN used to treat it which was not optimum for the rumen microbes to act effectively on the material. This result is in contrast to other workers who reported that treatment with urea increased the degradability of crop residues (Smith, 2002a; Fadel Elseed *et al.,* 2003; Khan *et al.,* 2006; Sarnklong *et al.,* 2010; Abdel Hameed *et al.,* 2013; Gunun *et al.,* 2013). However, the findings of this study for DM disappearance from the residues after 48 hours and even after 96 hours of incubation were not up to 40–50% which Preston (1986) recommended to warrant further consideration as a ruminant feed resources. Thus, it should be subjected to further treatment.

5.6.1.2 Degradation constants of GNS materials

Significant differences that were observed in the soluble fraction obtained in this study might be as a result of the variation in the chemical compositions in the content of the soluble fractions of the GNS materials. It was highest in UTGNS and lowest in ULGNS. The increase might be as a result of particle size reduction and pore size of the nylon bag (Ngele *et al.,* 2009). The results from this study is in contrast with the findings of some researchers that treatment with chemicals increased the solubility of crop residues (Ngele *et al.,* 2009; Maheri-sis *et al.,* 2011; Akinfemi *et al.,* 2012; Karimi *et al.,* 2014).

The value obtained with UTGNS material for the degradable fraction in the rumen suggest that the GNS was able to provide an adequate environment for the microbes to degrade the material (Orden *et al.,* 2000); adequate cellulose was available for microbial digestion (Karimi *et al.,* 2014) or the dustiness of the particle to escape the pore size of the nylon bag used for the study (Ngele *et al.,* 2009). This result was in contrast to some workers who showed that there was low degradability in crop materials that have high NDF and ADF content (Chaudhry, 2000; Abdu *et al.,* 2011; Karimi *et al.,* 2014).

Though, UTGNS had the highest percentage of lignin, NDF and ADF, it still had the fastest degradability. Nevertheless, the water soluble fraction along with the slowly degradable fraction adds up to the figure (‘a+b’). This result is in contrast with the works of Abdu *et al.,* (2011) who reported that high lignin content may result in low degradability. The higher value of the potential degradability of UTGNS resulted from the cumulating values of both the water soluble fraction and the slowly degradable fraction. This suggests that UTGNS has the potential to degrade more in the rumen compared to the other treated materials.

The higher results obtained in UTGNS might be attributed to the favourable rumen pH (Chaudhry, 2000) provided by the UTGNS used in the study. This was in contrast with the findings of some workers (Orden *et al.,* 2000; Ikhimioya *et al.,* 2005; Ngele *et al.,* 2009; Akinfemi *et al.,* 2012) who reported lower rate of degradation of untreated crop residues when fed to sheep.

The results of ED at 2 to 12% h^{-1} indicated a marked decrease in ED as the rumen outflow rate increased. This might be as a result of the reduced time spent in the rumen as the outflow rate increased. It might also be as a result of the fractional rate of passage when increased, it decreases the fractional rate of rumen degradability (Abdu *et al.*, 2011). It might also be as a result of the influence of the water soluble fraction and the rate at which ‘b’ fraction is degraded which results to an outflow rate of small particles (Ørskov, 1995). All the residues studied had less than 50% ED values at all outflow rates. This is a confirmation of the general low quality ascribed to crop residues. The higher ED values in UTGNS might be attributed to the effect of degradable substances on the extent and rate of degradation in sheep as reported by Orden *et al.* (2000) that negative effect of degradation of nutrients of low quality roughage was overcome without treatment. This was in contrast with the findings of Orden *et al.* (2000); Ikhimioya *et al.* (2005); Ngele *et al.* (2009); Sarnklong *et al.* (2010). The lower ED values of ULGNS in this study might be due to the greater effect of lime on the lignin molecules that inhibit rumen microbes and consequently rumen degradation of straw (Chaudhry, 2000) or the degradation of the cell wall constituent was not overcome by the treatment with urea-lime chemical (Orden *et al.*, 2000).

5.6.2 Disappearance and Degradation Characteristics of the GNS Based Diets

5.6.2.1 Disappearance of DM

The disappearance of the DM in the GNS based diets by the end of 48 hours of incubation is generally considered to be equivalent to digestibility and being the mean retention time of fibrous feeds in ruminants (Ikhimioya *et al.*, 2005). The significant differences observed in the GNS based diets could be due to variations in the chemical composition in the contents of the readily fermentable carbohydrates and their cell wall contents. However, the degradation for various GNS based diets differed with the change in chemical and incubation times.

While treatments modified cell wall composition and increased *in sacco* degradation of GNS based diets compared to the untreated GNS, the extent and increase depend on the type of chemical used. The higher value of UTGNS based diet at 0h might be attributed to the high solubility of other constituent feed included in the diet (Promkot and Wanapat, 2003).

ULGNS based diets had the highest degradability compared to other treatment diets. This suggest that there was a suitable amount of non-protein nitrogen in the diet that favours the activities of the microbes in the rumen to function effectively (Maheri-sis *et al.,* 2011); low cell wall and the presence of more soluble materials (Aregheore, 2000); it had the tendency to undergo a greater degree of particle disintegration which provide better adhesion sites for microbial attachment and activity (Orden *et al.,* 2000). LGNS were significantly lower at 0h, 3h, 6h, and 12h compared to other treatment diets suggesting the solubility of lime in the diet was low, especially at 0h (Sarnklong *et al.*, 2010) and the ruminal microbes could not readily degrade the diet in the first 12 hours of intake. Though, UTGNS based diet had the lowest value at incubation time 24, 36, 48h, this indicate that the level of NDF in the diets might have brought about this result or the microbes were not able to degrade the diet to a higher extent in 48 hours compared to other diets.

5.6.2.1 Degradation constants of the GNS based diets

The significant differences observed in soluble fractions ‘a’ could be due to variations in the chemical compositions in the contents of the readily fermentable carbohydrates. Soluble fraction was highest with UTGNS diet (40.4%) and lowest LGNS diet (36.11%). The increase in soluble fractions may have resulted from the more soluble carbohydrates in the diets which vary between treatment diets fed to the animals. According to Van Soest (1982), the soluble carbohydrates ferment faster than structural carbohydrates.

The decrease in the DM of potentially degradable fractions ‘b’ was least in UTGNS (19.49%). High NDF with UTGNS, suggest a high lignin content which may have resulted in the low rate of degradation, which might limit the rate of degradation in the rumen (Abdu *et al.,* 2011). The increase in potentially degradable fraction observed in both UGNS and LGNS was possibly influenced by the carbohydrate fraction readily available for the rumen microbial population (Akinfemi *et al.,* 2012). It might also be as a result of the breakdown of the glucosidic linkages in the GNS as a result of treatment. This is consistent with earlier report (Ngele *et al.,* 2009) who used urea to treat sorghum stover, maize stover and sugar cane bagasse but in contrast with the findings of Chaudhry (2000) who reported the degradation of lime treated wheat straw to be low. The difference in the degradable fraction observed with deferent chemical treatment might be as a result of their variable chemical compositions, especially the proportion of cell wall and its composition (Abdu *et al.,* 2011).

The potentially degradable DM fraction is of interest because it measures the proportion that is fermentable if this component does not bypass the rumen. Chemical treatment resulted in higher degradability of GNS based diets. With slowly but potentially degradable fraction ‘b’ in the urea and lime treated based diets; increased potential degradability ‘a+b’ was enhanced. This was similar to the results obtained by Orden *et al.* (2000) on rice straw treated with ammonia who reported that the potential degradability of straw increased due to higher ‘b’ value as a result of ammonia treatment. In another study, Chaudhry (2000) reported that treatment of wheat straw with lime had a greater a+b value than treatment with NaOH. Thus, this might be attributed to the effect of urea or lime in modifying the GNS cell wall components which improved its degradability (Fondevila *et al.,* 1994; Orden *et al.,* 2000); their low cell wall and presence of more soluble materials (Aregheore, 2000) or it contained adequate amount of nutrients to meet microbial growth requirements (Migwi *et al.,* 2011).

The rate of degradation per hour (‘c’) for the GNS based diets was observed to be significantly higher with UTGNS based diets and lower with LGNS based diets. High ADF and lignin content in the diet (Abdu *et al.,* 2011) suggest the low rate of degradation of the LGNS diet. The higher values observed for UTGNS based diet in this study falls within values reported for crop residues: millet = 0.023–0.035; sorghum = 0.028–0.038, (Ngele *et al.,* 2009). This result may be attributed to the particle size, rumen condition and diet composition of the host animal (Chaudhry, 2000). This findings was in contrast with the result obtained by Akinfemi *et al.* (2012).

The results of effective degradability ED at rumen outflow rates of 2, to 12% h^{-1} presented in Table 4.7 followed a characteristic pattern. There was a marked decrease in ED as the rumen out flow rate increased. This might be due to the reduced time spent in the rumen as the outflow rate increased (Abdu *et al.,* 2011). It might also be due to the increase in the outflow rate that leads to the corresponding decrease in the degradability of the diets (Ngele *et al.,* 2009). Increased fractional rate of passage (Abdu *et al.,* 2011) decreases fractional rate of rumen protein degradability. This may have been responsible for the decreased ED when rumen outflow rate increased. The lower ED value observed in UTGNS based diets at 2% outflow rate might be as a result of influence of the rapidly soluble fraction ‘a’ and the rate constant ‘c’ for the degradation of GNS (Ngele *et al.,* 2009). The higher value obtained for ULGNS based diet might be as a result of the ammonia hydrolysed from the combination of urea and lime included in the diet which was enough to cause a reasonable breakdown of the lignocelluloses to enable the microbes act on it effectively in the rumen (Ngele *et al.,* 2009). It also suggest that the diet had higher degradable nutrient leaving the rumen (Bo *et al.,* 2012) or high intake of feed (Filho *et al.,* 2003).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The results of this study, indicated that

- Treatment of groundnut shells with 2.5% urea and 2.5% lime increased the crude protein (CP) content by 100%.
- The treatment of groundnut shells with 2.5% urea and 2.5% lime increased the CP intake in Yankasa rams by 5.7g/day.
- The treatment of groundnut shells with 2.5% urea and 2.5% lime increased the matter digestibility by 7.4% in Yankasa rams.
- The urea and lime treatment of groundnut shells did not improve the rate of dry matter disappearance of the groundnut shells. The fastest disappearance was obtained in UTGNS at all incubation periods.
- Urea and lime treatment improved the rate of dry matter disappearance of the experimental diets at all incubation periods except at 6h which was fastest in UTGNS (35.85%).

The results offer additional information and practical data on the use of low quality roughage such as groundnut shells with effective chemical treatment. Therefore, it concluded that groundnut shell treated with urea and lime chemical could improve the nutritive value of groundnut shells through enhanced voluntary intake, digestibility, and rumen degradability in Yankasa rams.

6.2 Recommendations

- The study suggested that urea and lime treated groundnut shells can be used as alternative source of roughage for Yankasa rams.
- Therefore, urea and lime treated groundnut shells can be recommended as a source of non-conventional leguminous crop residue for Yankasa rams which is practical and applicable for use under farm conditions during off season.

REFERENCES

Abdel Hameed, A. A., Fedel Elseed, A. M., and Salih, A. M. (2013). Growth Performance and Rumen Fermentation of Lambs Fed Untreated or Urea Treated Groundnut Hull with Different Protein Sources. *Journal of Animal Production Advances*, *3*(3), 86–96. doi:10.5455/japa.20130320024314

Abdu, S. B., Hasan, M. R., Adamu, H. Y., Yashimi, S. M., and Abdullahi, M. J. (2012). Intake, Nutrient Digestibility and Nitrogen Balance of *Acacia auriculate, Gmelina arborea, Albizia lebbeck* and *Butryospermum parkii* by Yankasa Bucks. *Iranian Journal of Applied Animal Science*, *2*(2), 121–125. Retrieved from www.ijas.ir

Abdu, S. B., Hassan, M. R., Adamu, H. Y., and Yashim, M. (2011). Effect of Level of Zizyphus mauritiana Leaf Meal Inclusion in Concentrate Diet on Rumen Degradation Characteristics. *World Journal of Life Science and Medical Research*, *1*(6), 117–121.

Adamafio, N. A., Addo, P., Osei-Boadi, K., and Janha, R. (2012). Potash Pre-treatment Enhances Carbohydrate Biodegradability and Feed Potential of Groundnut (*Arachis hypogia*) Shell Meal.pdf. *Journal of Applied Sciences*, *12*(6), 1408–1412. doi:10.3923/jas.2012.1408.1412

Adamu, A. M., Adu, I. F., Olorunju, S. A. S., Alawa, C. B. I., and Lamidi, O. S. (1995). Effects of urea-ammoniation and cotton seed cake supplementation on the utilization of sorghum Stover by sheep. *Nigerian Journal of Animal Production*, *23*(2), 147–152.

Ago, Y. A. (2013). The Problem of Livestock Production Is Feeding. *AGRONIGERIA, Daily Trust*, p. 2. Abuja. Retrieved from http://agronigeria.com.ng/2013/09/12/the-problem-of-livestock-production-is-feeding/

Ahmed, B. (2002). Marketing of Small Ruminants in Nigeria. In C. A. . Lakpini, A. M. Adamu, O. W. Ehoche, and J. O. Gefu (Eds.), *Small Ruminant Production Training Workshop* (First., p. 97). Zaria: National Animal Proiduction Research Institute, Shika.

Ajala, M. K., Lamidi, O. S., and Otaru, S. M. (2008). Peri-Urban Small Ruminant Production in Northern Guinea Savanna, Nigeria. *Asian Journal of Animal and Veterinary Advances*, *3*, 138–146. doi:10.3923/ajava.2008.138.146

Akinfemi, A. (2010). Bioconversion of peanut husk with white rot fungi: *Pleurotus ostreatus* and *Pleurotus pulmonarius*. *Livestock Research for Rural Development*, *22*(3), 1–11. Retrieved from http://www.lrrd.org/lrrd22/3/akin22049.htm

Akinfemi, A., Adua, M. M., and Adu, O. A. (2012). Evaluation of nutritive values of tropical feed sources and by-products using in vitro gas production technique in ruminant animals. *Emirate Journal of Food and Agriculture*, *24*(4), 348–353. Retrieved from http://ejfa.info/

Al-masri, M. R., and Guenther, K. D. (1999). Changes in digestibility and cell-wall constituents of some agricultural by-products due to gamma irradiation and urea treatments. *Radiation Physics and Chemistry*, *55*, 323–329.

Alu, S. E., Adua, M. M., Damulak, H. I., Umar, R. S., Abubakar, A. D., and Matthew, U. D. (2012). Growth rate and nutrient digestibility by broiler birds fed alkali-treated groundnut (*Arachis hypogea*) shell meal-based diets. *Scholarly Journal of Agricultural Science*, *2*(10), 231–237.

Amodu, J. T., and Otaru, S. M. (2004). Production and Utilization of Browse Plants. In J. T. Amodu and J. O. Gefu (Eds.), *Forage Production and Management in Nigeria* (p. 89). Zaria: National Animal Production Research Institute, Shika.

AOAC, (Association Of Analytical Chemist). (2005). *Official Method of Analysis* (17th ed.). Maryland, USA: AOAC International.

Aregheore, E. M. (2000). Chemical composition and nutritive value of some tropical by-product feedstuffs for small ruminants - in vivo and in vitro digestibility. *Animal Feed Science and Technology*, *85*(2), 99–109. Retrieved from www.elsevier.com/locate/anifeedsci

Aregheore, E. M. (2009). *Country Pasture/Forage Resource Profiles*. Rome: Food and Agricultural Organisation (FAO). Retrieved from www.fao.org/ag/agp/agpc/doc/counprof/nigeria/nigeria.htm

Aribido, S. O. (2011). *ANP 202: Principles of Animal Production*. (A. Adebanjo and J. Sanusi, Eds.). Lagos: National Open University of Nigeria. Retrieved from http://www.nou.edu.ng/NOUN_OCL/pdf/pdf2/ANP 202.pdf

Assefa, D., Nurfeta, A., and Banerjee, S. (2013). Assessment of feed resource availability and livestock production constraints in selected Kebeles of Adami. *African Journal of Agricultural Research*, *8*(29), 4067–4073. doi:10.5897/AJAR2013.7096

Bastos, M. P. V., Carvalho, G. G. P. De, Pires, A. J. V., Silva, R. R., Filho, A. E., dos Santos, E. D. J., … Filho, G. A. (2014). Ingestive Behavior and Nitrogen Balance of Confined Santa Ines Lambs Fed Diets Containing Soybean Hulls. *Asian-Australasian Journal of Animal Sciences*, *27*(1), 24–29. Retrieved from http://dx.doi.org/10.5713/ajas.2013.13076 www.ajas.info

Bawa, G. S. (2014). Advanced Feeds and Feeding. Zaria, Kaduna.

Beauchemin, K. A., Colombatto, D., and Morgavi, D. P. (2004). A rationale for the development of feed enzyme products for ruminants. *Canadian Journal of Animal Science*, *84*, 23–36.

Bhasker, T. V., Nagalakshmi, D., and Rao, D. S. (2013). Development of appropriate fibrolytic enzyme combination for maize stover and its effect on rumen fermentation in sheep. *Asian-Australasian Journal of Animal Sciences*, *26*(7), 945–51. doi:10.5713/ajas.2012.12590

Bheekhee, H., Hulman, B., Boodoo, A. A., Ramnauth, R. K., Lam heung yuen, R., Fakim, R., and Dobee, B. (2002). Development and Field Evaluation of Animal Feed Supplementation Packages for Improving Meat and Milk Production in Ruminant Livestock using locally available Feed Resources. In IAEA (Ed.), *Proceedings of the* *final review meeting of an IAEA Technical Co-operation Regional AFRA Project organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Cairo, Egypt, 25–29 November 2000* (p. 170). Vienna, Austria: International Atomic Energy Agency (IAEA).

Bo, Y. K., Yang, H. J., Wang, W. X., Liu, H., Wang, G. Q., and Yu, X. (2012). Metabolisable Energy, In situ Rumen Degradation and In vitro Fermentation Characteristics of Linted Cottonseed Hulls, Delinted Cottonseed Hulls and Cottonseed Linter residue. *Asian-Australasian Journal of Animal Sciences*, *25*(2), 240–247.

Can, A., Denek, N., Tufenk, S., and Bozkurt, A. (2004). Determining Effect of Lime and Urea Treatment on Crude and Digestible Nutrient Content of Wheat Straw. *Journal of Animal and Veterinary Advances*, *3*(7), 479–482.

Chaudhry, A. S. (1998). Nutrient composition, digestion and rumen fermentation in sheep fed wheat straw treated with calcium oxide, sodium hydroxide and alkaline hydrogen peroxide. *Animal Feed Science and Technology*, *74*, 315–328.

Chaudhry, A. S. (2000). Rumen degradation in sacco in sheep of wheat straw treated with calcium oxide , sodium hydroxide and sodium hydroxide plus hydrogen peroxide. *Animal Feed Science and Technology*, *83*(1), 313–323. Retrieved from www.elsevier.com/locate/anifeedscii

Devendra, C. (1990). Feed Resource Development from Agro-Industrial By-Products and Their Efficient Utilisation in South East Asia and the Pacific. In *Paper presented at a Regional Seminar on Management and Utilisation of Agricultural and Industrial Wastes 21-23 March 1990, Kuala Lumpur, Malaysia* (p. 27). Kuala Lumpur, Malaysia: IDRC - Llb.

Devendra, C., and McLeroy, G. B. (1982). *Goat and Sheep Production in the Tropics*. (W. J. A. Payne, Ed.) (First Edit.). London: Longman Group Limited.

Distel, R. A., Villalba, J. J., and Laborde, H. E. (1994). Effects of early experience on voluntry intake of low-quality roughage by sheep. *Journal of Animal Science*, *72*, 1191–1195.

Doma, U. D., Mohammed, L. K., and Umeh, A. P. (1999). Observation on the characteristics of small holder sheep and goat management practice in old Bauchi State. *Tropical Journal of Animal Science*, *2*, 125–130.

DPI, (Department of Primary Industries). (2007). *Drought Feeding and Management of Sheep: A guide for farmers and land managers*. (J. Court, Ed.) (Forth.). Victoria, Australia: Department of Primary Industries, Victorian Goverment.

Fadel Elseed, A. M. A. (2005). Effect of supplemental protein feeding frequency on ruminal characteristics and microbial N production in sheep fed treated rice straw. *Small Ruminant Research*, *57*(1), 11–17. doi:10.1016/j.smallrumres.2004.04.013

Fadel Elseed, A. M. A., Sekine, J., Hishinuma, M., and Hamana, K. (2003). Effects of ammonia, urea plus calcium hydroxide and animal urine treatment on chemical composition and in sacco degradability of rice straw. *Asian-Australasian Journal of Animal Sciences*, *16*, 368–373.

Filho, S. de C. V., Pina, D. dos S., Chizzotti, M. L., and Valadares, R. F. D. (2003). Ruminal Feed Protein Degradation and Microbial. In *Nutrient requirement of Zebu beef cattle* (pp. 13–44). Paris: 1NCT-CA.

Fondevila, M., Castrillo, C., Gauda, J. A., and J Balcelis. (1994). Effect of ammonia treatment and carbohydrate suplementation of barley straw and rumen fluid characteristics and substrate degradation by sheep. *Animal Feed Science and Technology1*, *50*, 137–155.

Gao, W., Chen, A., Zhang, B., Kong, P., Liu, C., and Zhao, J. (2015). Rumen Degradability and Post-ruminal Digestion of Dry Matter , Nitrogen and Amino Acids of Three Protein Supplements. *Asian-Australasian Journal of Animal Sciences*, *28*(4), 485–493.

Gefu, J. O. (2002). Socioeconomic Cosideration in Small Ruminant Proction. In C. A. . Lakpini, A. M. Adamu, O. W. Ehoche, & J. O. Gefu (Eds.), *Small Ruminant Production Training Workshop* (First., p. 97). Zaria: National Animal Production Research Institute, Shika.

Georing, H. K., and Van Soest, P. J. (1970). *Forage Fibre Analysis (Apparatus, Reagents, Procedures and some Applications)*. Washington, DC: U.S. Agricultural Reserch Service.

Glatzle, A. (1992). Feed Resources in the Sahel. *Animal Research and Development*, *35*, 43–58.

Grovum, W. L. (1988). Appetite, palatability and control of feed intake. In D. C. Church (Ed.), *The Ruminant Animal* (pp. 202–216). Pretence-Hall, Englewood Cliffs, NJ.

Gunun, P., Wanapat, M., and Anantasook, N. (2013a). Effects of Physical Form and Urea Treatment of Rice Straw on Rumen Fermentation , Microbial Protein Synthesis and Nutrient Digestibility in Dairy Steers. *Asian-Australasian Journal of Animal Sciences*, *26*(12), 1689–1697. Retrieved from http://dx.doi.org/10.5713/ajas.2013.13190

Gunun, P., Wanapat, M., and Anantasook, N. (2013b). Rumen Fermentation and Performance of Lactating Dairy Cows Affected by Physical Forms and Urea Treatment of Rice Straw. *Asian-Australasian Journal of Animal Sciences*, *26*(9), 1295–1303. Retrieved from http://dx.doi.org/10.5713/ajas.2013.13094

Hernández, I., and Sánchez, M. D. (2014). *Small ruminant management and feeding with high quality forages in the Caribbean*. (M. D. H. Sánchez and I. V. Hernández, Eds.). Santo Domingo, Dominican Republic: Interamerican Institute Of Cooperation In Agriculture (IICA).

Horne, P. M., and Stür, W. W. (2001). *Developing forage technologies with smallholder farmers - how to grow, manage and use forages*. ACIAR Monograph.

Hossain, M. M., Khan, M. J., and Akbar, M. A. (2010). Nutrient digestibility and growth of local bull calves as affected by feeding urea and urease enzyme sources treated rice straw. *Bangladish Journal of Animal Science*, *39*, 97–105.

Hostville. (2013). Upgrading Crop Residues for Effective Utilization by Ruminant Livestock. *Resourcedat*. Retrieved August 24, 2015, from http://resourcedat.com/document/upgrading-crop-residues-for-effective-utilization-by-ruminant-livestock/

Huyen, N. T., Wanapat, M., and Navanukraw, C. (2012). Effect of mulberry leaf pellet (MUP) supplementation on rumen fermentation and nutrient digestibility of beef cattle fed on rice straw-based diets. *Animal Feed Science Technology*, *175*, 8–15.

Ibrahim, H. (1998). *Small Ruminant Production Techniques*. (H. Ibrahim, Ed.) (ILRI Manua.). Nairobi, Kenya: ILRI (International Livestock Research Institute).

Ikhimioya, I., Isah, O. A., Ikhatua, U. J., and Bamikole, M. A. (2005). Rumen Degradability of Dry Matter and Crude Protein in Tree Leaves and Crop Residues of Humid Nigeria. *Pakistan Journal of Nutrition*, *4*(5), 313–320. Retrieved from http://www.pjbs.org/pjnonline/fin330.pdf

Iro, I. (2012). *Diffusion of Innovation: The Fulani Response to Livestock Improvement*. Washington, D.C., USA. Retrieved from http://www.gamji.com/fulani12.htm#

Jayasuriya, M. C. N. (2002). Principles of Ration Formulation for Ruminants. In IAEA (Ed.), *Proceedings of the final review meeting of an IAEA Technical Co-operation Regional AFRA Project organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Cairo, Egypt, 25–29 November 2000* (p. 170). Vienna, Austria: International Atomic Energy Agency (IAEA).

Jokthan, G. E. (2014). *AEM 722: Ruminant Animals*. (G. E. Jokthan, Ed.). Lagos: National Open University of Nigeria. Retrieved from http://www.nou.edu.ng/noun_ocl/pdf/sst/aem 722 ruminant animals.pdf

Kallah, M. S. (2004). Rangelands in Nigeria: Partial Resource Appraisal Towards Improving Livestock Production. In J. O. Gefu & J. T. Amodu (Eds.), *Forage Production and Management in Nigeria* (p. 89). Zaria: National Animal Production Research Institute, Shika.

Karimi, A. H., Acda, S. P., Capitan, S. S., Laurena, A. C., Tambalo, F. Z., Angeles, A. A., … Sevilla, C. C. (2014). In Situ Cattle Rumen Degradability of Urea- Molasses and Cellulase Treated Rice Straw. *Annual Research & Review in Biology*, *4*(22), 3420–3428.

Khan, M. A., Sarwar, M., Nisa, M., Khan, M. S., Bhatti, S. A., Iqbal, Z., … Ki, K. S. (2006). Feeding Value of Urea Treated Wheat Straw Ensiled with or without Acidified Molasses in Nili-Ravi Buffaloes. *Asian-Australasian Journal of Animal Sciences*, *19*(5), 645–650.

Kholif, A. E., Khattab, H. M., El-Shewy, A. A., Salem, A. Z. M., Kholif, A. M., El-Sayed, M. M., … Mariezcurrena, M. D. (2014). Nutrient Digestibility , Ruminal Fermentation Activities , Serum Parameters and Milk Production and Composition of Lactating Goats

Fed Diets Containing Rice Straw Treated with Pleurotus ostreatus. *Asian-Australasian Journal of Animal Sciences*, *27*(3), 357–364.

Kibon, A., and Ørskov, E. R. (1993). The Use of Degradation Characteristics of Browse Plants to Predict Intake and Digestibility by Goats. *Journal of Animal Production*, *57*(2), 247–251. Retrieved from http://dx.doi.org/10.1017/S0003356100006851

Kwari, I. D., Igwebuike, J. U., Shuaibu, H., Titimaand, S. I., and Raji, A. O. (2014). Growth and Carcass Characteristics of Broiler Chickens Fed Maize, Sorghum, Millet and their Combinations in the Semi-Arid Zone of Nigeria. *International Journal of Science and Nature*, *5*(2), 240–245.

Laconi, E. B., and Jayanegara, A. (2015). Improving Nutritional Quality of Cocoa Pod (Theobroma cacao) through Chemical and Biological Treatments for Ruminant Feeding : In vitro and In vivo Evaluation. *Asian-Australasian Journal of Animal Sciences*, *28*(3), 343–350.

Lakpini, C. A. M. (2002). Feeds and Feeding Strategies for Small Ruminants in various Physiological States. In C. A. . Lakpini, A. M. Adamu, O. W. Ehoche, and J. O. Gefu (Eds.), *Small Ruminant Production Training Workshop* (First., p. 97). Zaria: National Animal Production Research Institute, Shika.

Larbi, A., Dung, D. D., Olorunju, P. E., Smith, J. W., Tanko, R. J., Muhammad, I. R., and Adekunle, I. O. (1999). Groundnut (Arachis hypogaea) for food and fodder in crop-livestock systems: forage and seed yields, chemical composition and rumen degradation of leaf and stem fractions of 38 cultivars. *Animal Feed Science and Technology*, *77*(8), 33–47.

Lardy, G., and Anderson, V. (2009). *Alternative Feeds for Ruminants* (Revised.). Fargo, North Dakota: North Dakota State University Extension Service. Retrieved from www.ag.ndsu.nodak.edu

Lawal-Adebowale, O. A. (2012). Dynamics of Ruminant Livestock Management in the Context of the Nigerian Agricultural System. In K. Javed (Ed.), *Livestock Production* (p. 150). Abeokuta, Nigeria: InTech. doi:10.5772/2730

Lemus, R., and Brown, K. (2008). Feeding Small Ruminants: Developing a Grazing System for Sheep and Goats. *Cooperative Extension Service; Mississippi State University*, 1–4.

Lenne, J. M., and Wood, D. (2004). Is there logic for fodder legumes in Africa? *Food Policy*, *29*, 565–585.

Li, J., Shen, Y., and Cai, Y. (2010). Improvement of Fermentation Quality of Rice Straw Silage by Application of a Bacterial Inoculant and Glucose. *Asian-Australasian Journal of Animal Sciences*, *23*(7), 901–906.

Logbaby. (2013). Food Security And Poverty Alleviation In Nigeria: The Livestock Perspective. *The Leadership News*, p. 3. Abuja. Retrieved from http://logbaby.com/news/food-security-and-po_15787.html#

Lukuyu, B. A., Kitalyi, A., Franzel, S., Duncan, A., and Baltenweck, I. (2009). *Constraints and options to enhancing production of high quality feeds in dairy production in Kenya, Uganda and Rwanda* (ICRAF Work.). Nairobi, Kenya: World Agroforestry Centre.

Lukuyu, B., Franzel, S., Ongadi, P. M., and Duncan, A. J. (2011). Livestock feed resources: Current production and management practices in central and northern rift valley provinces of Kenya. *Livestock Research for Rural Development*, *23*(5), 103–112. Retrieved from http://www.lrrd.org/lrrd23/5/luku23112.htm

Maheri-sis, N., Abdollahi-ziveh, B., Salamatdoustnobar, R., and Ahmadzadeh, A. (2011). Determining Nutritive Value of Soybean Straw for Ruminants Using Nylon Bags Technique, *10*(9), 838–841.

Makkar, H. P. S. (2002a). Applications of the In Vitro Gas Method in the Evaluation of Feed Resources, and Enhancement of Nutritional Value of Tannin-Rich Tree/Browse Leaves and Agro-Industrial By-Products. In IAEA (Ed.), *Proceedings of the final review meeting of an IAEA Technical Co-operation Regional AFRA Project organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Cairo, Egypt, 25–29 November 2000* (p. 170). Vienna, Austria: International Atomic Energy Agency (IAEA).

Makkar, H. P. S. (2002b). Project Summary: Development and Field Evaluation of Animal Feed Supplementation Packages (Afra Project Ii-17 - Raf/5/041). In IAEA (Ed.), *Proceedings of the final review meeting of an IAEA Technical Co-operation Regional AFRA Project organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Cairo, Egypt, 25–29 November 2000* (p. 170). Vienna, Austria: International Atomic Energy Agency (IAEA). Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Development+and+field+evaluation+of+animal+feed+supplementation+packages#0

Malau-Aduli, B. S., Eduvie, L., Lakpini, C. A. M., and Malau-Aduli, A. E. O. (2003). Chemical compositions, feed intakes and digestibilities of crop-residue based rations in non-lactating Red Sokoto goats in the sub-humid zone of Nigeria. *Animal Science Journal*, *74*(2), 84–94.

Marghazani, I. B., Kakar, M. A., Kakar, M. H., Chachar, B., Hameed, A., Jan, M., and Nawaz, A. (2014). Livestock Feed Resources and Feeding Practices in Balochistan. *Journal of Animal & Plant Sciences*, *24*(1), 87–90.

Mbewe, M. R., Hamandishe, V. R., and Masunda, B. (2014). Nitrogen Balance and Rumen Microbial Protein Synthesis in Goats Fed Diets Containing Soaked and Roasted Mucuna Bean (Mucuna pruriens). *Online Journal of Animal and Feed Research*, *4*(1), 6–9. Retrieved from http://www.science-line.com/index/

McDonald, P., Edwards, R. A., Greenhalgh, J. F. D., Morgan, C. A., Sinclair, L. A., and Wilkinson, R. G. (2010). *Animal Nutrition*. (C. A. Morgan, J. F. D. Greenhalgh, L. A. Sinclair, & R. G. Wilkinson, Eds.) (Seventh.). Harlow, England: Prentice Hall.

Melaku, S., Peters, K. J., and Tegegne, A. (2004). Intake, digestibility and passage rate in Menz sheep fed tef (Eragrostis tef) starw supplemented with dried leaves of selected multipurpose trees, thier mixtures or wheat bran. *Small Ruminal Research*, *56*, 139–149.

Migwi, P. K., Godwin, I., Nolan, J. V, and Kahn, L. P. (2011). The Effect of Energy Supplementation on Intake and Utilisation Efficiency of Urea-treated Low-quality Roughage in Sheep I . Rumen Digestion and Feed Intake. *Asian-Australasian Journal of Animal Sciences*, *24*(5), 623–635. doi:10.5713/ajas.2011.10282

Mohammed, A. K. (2002). Common Health Problems of Small Ruminants and their Control. In C. A. . Lakpini, A. M. Adamu, O. W. Ehoche, and J. O. Gefu (Eds.), *Small Ruminant Production Training Workshop* (First., p. 97). Zaria: National Animal Production Research Institute, Shika.

Ndemanisho, E. E., Kimoro, B. N., Mtengeti, E. J., and Muhikambele, V. R. M. (2007). In vivo digestibility and performance of growing goats fed maize stover supplemented with browse leaf meals and cotton seed cake based concentrates. *Livestock Research for Rural Development*, *19*(8), 1–13. Retrieved from http://www.lrrd.org/lrrd19/8/ndem19105.htm

Ngele, M. B., Adegbola, T. A., Bogoro, S. E. S., Abubakar, M., and Kalla, D. J. U. (2009). Rumen degradability and kinetic properties of urea and poultry litter treated rice straw
. صد ئا صخلا ةي كرحلا ةي لدحلا تلا شدقل زرلأا لماعملا اي روي لااب ت لاضد فو) قرز (روي طلا
Emirate Journal of Food and Agriculture, *21*(1), 32–39.

Nguyen, V. T., Orr, A. I., St. Louis, D. G., and Rude, B. J. (2007). Supplementing corn or soybean hulls to cattle fed bermudagrass hay II: In situ disappearance and ruminal dynamics. *Journal of Animal and Veterinary Advances*, *6*(9), 1125–1134.

NRC, (National Research Council). (2007). *Nutritional Requirements of Domestic Animals: Nutrient Requirments of Sheep*. ((National Research Council) NRC, Ed.) (Seventh Re.). Washington DC, USA.: National Academies Press.

Ondiek, J. O., Ogore, P. B., Shakala, E. K., and Kaburu, G. M. (2013). Feed intake , digestibility and performance of growing small East African goats offered maize (Zea mays) stover supplemented with Balanites aegyptiaca and Acacia tortilis leaf forages. *Basic Research Journal of Agricultural Science and Review*, *2*(1), 21–26. Retrieved from www.basicresearchjournals.org

Oni, O. O. (2002). Breeds and Genetic Improvement of Small Ruminants (Sheep and Goat). In C. A. . Lakpini, A. M. Adamu, O. W. Ehoche, and J. O. Gefu (Eds.), *Small Ruminant Production Training Workshop* (First., p. 97). Zaria: National Animal Production Research Institute, Shika.

Orden, E. A., Yamaki, K., Ichinohe, T., and Fujihara, T. (2000). Feeding Value of Ammoniated Rice Straw Suplimented with Rice Bran in Sheep: II. In Situ Rumen Degradation of Untreated and Ammonia Treated Rice Straw. *Asian-Australasian Journal of Animal Sciences*, *13*(7), 906–912.

Ørskov, E. R. (1995). Plant factors limiting roughage intake in ruminants. In *Tropical Feeds and Feeding Systems* (pp. 55–70). Bucksburn, Aberdeen: The Rowett Research Institute, International Feed Resources Centre. Retrieved from http://www.fao.org/livestock/agap/frg/ECONF95/PDF/ERO.PDF

Ørskov, E. R. (1999). Supplement strategies for ruminant and management of feeding to maximize utilization of roughages. *Preventive Veterenary Medicine*, *38*, 179–185.

Ørskov, E. R., DeB Hovell, F. D., and Mould, F. (1980). The Use of the Nylon Bag Technique for the Evaluation of Feedstuffs. *Tropical Animal Production*, *5*(3), 195–213. Retrieved from www.fao.org/livestock/agap/frg/TAP53/53_1.pd

Ørskov, E. R., and McDonald, I. (1979). The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *Journal of Agriculture Science (Cambridge)*, *92*(2), 499–503. doi:http://dx.doi.org/10.1017/S0021859600063048

Osinowo, O. A., Abubakar, B. Y., Adewuyi, A. A., Onifade, O. S., and Dennar, P. O. (1991). Estimates of genetic and phenotypic parameters of birth weight, weaning weight and pre-weaning gain in Yankasa sheep. In *The Proceedings of the 16th Annual Conference of the Nigerian Society for Animal Production, Usmanu Danfodio University*. Sokoto, Nigeria.

Osuji, P. O., Nsahlai, I. V, and Khalili, H. (1993). *Feed Evaluation* (ILCA manua.). Addis Ababa, Ethiopia: ILCA (International Livestock Centre for Africa).

Otaru, S. M., Adamu, A. M., Ehoche, O. W., and Makun, H. J. (2011). Effects of varying the level of palm oil on feed intake , milk yield and composition and postpartum weight changes of Red Sokoto goats. *Small Ruminant Research*, *96*(1), 25–35. doi:10.1016/j.smallrumres.2010.11.004

Pradhan, R., Tobioka, H., and Tasaki, I. (1997). Effect of moisture content and different levels of additives on chemical composition and in-vitro dry matter digestibility of rice straw. *Animal Science and Technology (Japan)*, *68*, 273–284.

Preston, T. R. (1986). *Better utilization of crop residues and by-products in animal feeding : research guidelines 2 . A practical manual for research workers* (second.). Rome: FAO Animal Production and Health Paper 50/2. Retrieved from http://www.fao.org/docrep/003/x6554e/x6554e00.htm#TOC

Preston, T. R., and Leng, R. A. (1987). *Matching Ruminant production system with Available Resources in the tropics and subtropics*. Arnidale NSW, Australia: Penambul Books Ltd. Retrieved from http://books.google.com.ng/books/about/Matching_Ruminant_Production_Systems_wit.html?id=hmy_aaaayaaj&redir_esc=y

Price, M. L. (2007). The Moringa Tree. ECHO technical note. Retrieved from http://chenetwork.org/files_pdf/Moringa.pdf

Promkot, C., and Wanapat, M. (2003). Ruminal degradation and intestinal digestion of crude protein of tropical protein resources using nylon bag technique and three-step in vitro procedure in dairy cattle. *Livestock Research for Rural Development*, *15*(11), 1–12.

Rabbit, S. J. (2012). *A Guide to Feed Planning for Sheep Farmers*. (New Zealand Beef + Lamb, Ed.) (Second.). New Zealand: New Zealand sheep council. Retrieved from www.beeflambnz.com

Rana, I. A. (1986). Groundnut Utilization for Food and Feeds. In M. A. Khan (Ed.), *Procedings National Groundnut Workshop , NARC, Islamabad. Feb 17-19, 1986* (pp. 175–190). Islamabad: National Agricultural Research Center.

Rasambainarivo, J. H., Razafindraibe, H., Rabehanitriniony, M., Rasoloarison, R., Rafalimanantsoa, E., and Barsona-fofifa-drzv, M. R. R. (2002). Responses to Dry Season Supplementation by Dairy Cows on the Highland Zones of Madagascar. In IAEA (Ed.), *Proceedings of the final review meeting of an IAEA Technical Co-operation Regional AFRA Project organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Cairo, Egypt, 25–29 November 2000* (p. 170). Vienna, Austria: International Atomic Energy Agency (IAEA).

Russell, J. B. (2002). Effects of urea, isolated soybean protein and blood meal on growing steers fed a corn-based diet. *Animal Feed Science Technology, 102*, 3–14.

Saadullah, M., Haque, M., and Dolberg, F. (1981). Treatment of rice straw with lime. *Tropical Animal Production, 6*(2), 116–120.

Sahoo, B., Saraswat, M. L., Haque, N., and Khan, M. Y. (2000). Energy balance and methane production in sheep fed chemically treated wheat straw. *Small Ruminal Research, 35*, 13–19.

Saleh, H. M., Elwan, K. M., El-fouly, H. A., Ibrahim, I. I., Salama, A. M., and Elashry, M. A. (2002). The Use of Poultry Waste as a Dietary Supplement for Ruminants. In IAEA (Ed.), *Proceedings of the final review meeting of an IAEA Technical Co-operation Regional AFRA Project organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Cairo, Egypt, 25–29 November 2000* (p. 170). Vienna, Austria: International Atomic Energy Agency (IAEA).

Santos, A. B., Pereira, M. L. A., Silva, H. G. O., Pedreira, M. S., Carvalho, G. G. P., Ribeiro, L. S. O., … Moreira, J. V. (2014). Nitrogen Metabolism in Lactating Goats Fed with Diets Containing Different Protein Sources. *Asian-Australasian Journal of Animal Sciences, 27*(5), 658–666. Retrieved from http://dx.doi.org/10.5713/ajas.2013.13493

Sarnklong, C., Cone, J. W., Pellikaan, W., and Hendriks, W. H. (2010). Utilization of Rice Straw and Different Treatments to Improve Its Feed Value for Ruminants : A Review. *Asian-Australasian Journal of Animal Sciences*, *23*(5), 680–692. Retrieved from www.ajas.info

SAS, (Statistical Analysis Systems). (2002). Procedures Guide. North Carolina, USA: Statistical Analysis Systems Institute, Cary.

Selim, A. S. M., Pan, J., Suzuki, T., Ueda, K., Kobayashi, Y., and Tanaka, K. (2002). Postprandial changes in particle associated ruminal bacteria in sheep fed ammoniated rice straw. *Animal Feed Science and Technology*, *19*, 227–287.

Selim, A. S. M., Pan, J., Takano, T., Suzuki, T., Koike, S., Kobayashi, Y., and Tanaka, K. (2004). Effect of ammonia treatment on physical strength of rice straw, distribution of straw particles and particle-associated bacteria in sheep rumen. *Animal Feed Science and Technology*, *115*, 117–128.

Simbaya, J. (2002a). Availability and Feeding Quality Characteristics of On-Farm Produced Feed Resources in the Traditional Small-Holder Sector in Zambia. In IAEA (Ed.), *Proceedings of the final review meeting of an IAEA Technical Co-operation Regional AFRA Project organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Cairo, Egypt, 25–29 November 2000* (p. 170). Vienna, Austria: International Atomic Energy Agency (IAEA).

Simbaya, J. (2002b). Potential of Fodder Tree/Shrub Legumes as a Feed Resource for Dry Season Supplementation of Smallholder Ruminant Animals. In IAEA (Ed.), *Proceedings of the final review meeting of an IAEA Technical Co-operation Regional AFRA Project organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Cairo, Egypt, 25–29 November 2000* (p. 170). Vienna, Austria: International Atomic Energy Agency (IAEA).

Singh, F., and Diwakar, B. (1993). *Nutritive Value and Uses of Pigeonpea and Groundnut* (Skill Deve.). Patancheru, Andhra Pradesh 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Smith, O. B. (1989). Utilization of crop residues in the nutrition of sheep and goats in the humid tropics of West Africa. In V. M. Timon & R. P. Baber (Eds.), *Proceedings of a seminar held in Yamoussoukro, Côte d'lvoire 21–25 September 1987* (pp. 1–16). Yamoussoukro, Côte d'lvoire: Agriculture and Consumer Protection, FAO. Retrieved from http://agris.fao.org/agris-search/search/display.do?f=1990/XF/XF90006.xml;XF9089075

Smith, T. (2002a). On-Farm Treatment of Straws and Stovers with Urea. In IAEA (Ed.), *Proceedings of the final review meeting of an IAEA Technical Co-operation Regional AFRA Project organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Cairo, Egypt, 25–29 November 2000* (p. 170). Vienna, Austria: International Atomic Energy Agency (IAEA).

Smith, T. (2002b). Some Tools to Combat Dry Season Nutritional Stress in Ruminants under African Conditions. In IAEA (Ed.), *Proceedings of the final review meeting of an IAEA Technical Co-operation Regional AFRA Project organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and held in Cairo, Egypt, 25–29 November 2000* (p. 170). Vienna, Austria: International Atomic Energy Agency (IAEA).

Squidoo. (2014). Peanut shell is Useful. Retrieved from http://www.squidoo.com/peanut-shell

Teklu, B., Negesse, T., and Angassa, A. (2011). Effect of farming systems on livestock feed resources and feeding systems in Benishangul-Gumuz region, western Ethiopia. *International Research Journal of Agricultural Science and Soil Science*, *1*(1), 20–28. Retrieved from http://interesjournals.org/IRJAS/Pdf/2011/March/Teklu et al.pdf

Trach, N. X., Mo, M., and Cu Xuan Dan. (2001a). Effects of treatment of rice straw with lime and or urea on responses of growing cattle. *Livestock Research for Rural Development, 13*(5), 1–9. Retrieved from http://www.cipav.org.co/lrrd/lrrd13/5/trach135.htm

Trach, N. X., Mo, M., and Cu Xuan Dan. (2001b). Effects of treatment of rice straw with lime and/or urea on its chemical composition, in-vitro gas production and in-sacco degradation characteristics. *Livestock Research for Rural Development*, *13*(4).

Vadiveloo, J. (2003). The effect of agronomic improvement and urea treatment on the nutritional value of Malaysian rice straw varieties. *Animal Feed Science and Technology, 108*, 33–146.

Van Soest, P. J. (1982). *Nutritional Ecology of the Ruminant*. Corvallis: OB Books.

Vyas, A., Vyas, D., and Vyas, K. M. (2005). Production and optimization of cellulases on pretreated groundnut shell by Aspergillus terreus AV49. *Journal of Scientific and Industrial Research*, *64*(4), 281–286.

Wambui, C. C., Abdulrazak, S. A., and Noordin, Q. (2006). Performance of Growing Goats Fed Urea Sprayed Maize Stover and Supplemented with Graded Levels of Tithonia Diversifolia, *19*(7), 992–996.

Wambui, C. C., Awano, T., Ando, S., Abdulrazak, S. A., and Ichinohe, T. (2010). Effect of yeast supplementation on in vitro ruminal degradability of selected browse species from Kenya. *Journal of Food, Agriculture & Environment*, *8*(2), 553–557.

Wanapat, M., Kang, S., Hankla, N., and Phesatcha, K. (2013). Effect of rice straw treatment on feed intake , rumen fermentation and milk production in lactating dairy cows. *African Journal of Agricultural Research*, *8*(17), 1677–1687. doi:10.5897/AJAR2013.6732

Wikipedia. (2015). The Free Encyclopaedia. *WIKIPEDIA*. Ahmadu Bello University. Retrieved January 24, 2015, from http://en.wikipedia.org/wiki/Ahmadu_Bello_University

World66. (2016). The Travel Guide. *Internet Brands Travel*. Retrieved October 12, 2016, from www.world66.com/africa/nigeria/zaria/lib/climate

Yami, A. (2008). Nutrition and Feeding of Sheep and Goats. In R. C. Merkel (Ed.), *Sheep and Goat Production Handbook for Ethiopia* (p. 345). Ethiopia Sheep and Goat Productivity Improvement Program, 2008. Retrieved from http://www.esgpip.org/handbook/Handbook_PDF/Chapter 7_ Nutrition and feeding of Sheep and Goats.pdf

Yang, H. E., Son, Y. S., and Beauchemin, K. A. (2011). Effects of Exogenous Enzymes on Ruminal Fermentation and Degradability of Alfalfa Hay and Rice Straw. *Asian-Australasian Journal of Animal Sciences*, *24*(1), 56–64.

Yulistiani, D., Jelan, Z. A., Liang, J. B., Yaakub, H., and Abdullah, N. (2015). Effects of Supplementation of Mulberry (Morus alba) Foliage and Urea-rice Bran as Fermentable Energy and Protein Sources in Sheep Fed Urea-treated Rice Straw Based Diet. *Asian-Australasian Journal of Animal Sciences*, *28*(4), 494–501. Retrieved from http://dx.doi.org/10.5713/ajas.14.0406

Zaman, M. S., and Owen, F. (1990). Effect of calcium hydroxide or urea treatment of barley straw on intake and digestibility in sheep. *Small Ruminant Research*, *3*, 237–248.

Zulkarnaini, Z., Zain, M., Jamarun, N., and Tjakradidjaya, A. (2012). Effect of Phosphorus Supplementation to Ammoniated Rice Straw on Rumen Fermentability , Microbial Protein Synthesis and in vitro Nutrient Degradability. *Iranian Journal of Applied Animal Science*, *2*(2), 163–166.

APPENDICES

Plate I: The improvised cannula used on the fistulated Yankasa rams

Plate II: The nylon bags arranged on the string alternatively and properly labelled before incubation.

Plate III: The Yankasa ram fixed with the improvised cannula as well as the nylon bags suspended in the rumen.