NUTRITIVE VALUE OF PROCESSED GROUNDNUT (*Arachis hypogaea* L.) HAULM-BASED DIETS FOR WEST AFRICAN DWARF RAMS

BY

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A thesis in the Department of Animal Science submitted to the Faculty of Agriculture in partial fulfillment of the requirement for the award of degree of

DOCTOR OF PHILOSOPHY

Of the

UNIVERSITY OF IBADAN

JULY, 2021

CERTIFICATION

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DEDICATION

This work is dedicated to Jesus Christ my Saviour, for without him I can do nothing.

ACKNOWLEDGEMENTS

For the Lord God will help me; therefore shall I not be confounded; therefore have I set my face like a flint, and I know that I shall not be ashamed. Isaiah 50: 7. Thank you Father for the fulfillment of your promises in my life.

My profound appreciation goes to my supervisor, Professor O. J. BabayemI, a very hard working, courageous, determined, versatile, innovative , 'workaholic Professor' and one of the best animal scientists in the entire universe today. I am grateful for the time spared to supervise this work out of your very busy schedule formerly as the Head of Department and later the Dean of the Faculty. Higher heights in Jesus name.

Also, I am greatly indebted to Professor M. K. Adewumi, an intelligent, thorough, thoughtful, experienced, meticulous, erudite scholar of international repute and one of the best ruminant experts of our time who dedicated part of his time to co-supervise this work in spite of his responsibility as the Head of Unit and other commitments.

My sincere appreciations goes to Dr. Badru for his guide in the extension aspects of the study. Special thanks to my lecturers, Profs Adejumo (HOD), Longe, Iyayi, Ologhobo, Omojola, Ososanya and Tewe (of blessed memory) and Drs. Adebiyi, Adeyemo, Olorunnisomo, Anurudu, Ajayi, Abu, Olusola, Ewuola, Sokunbi, Adeleye, Agboola, Osaiyuwa, Alaba and of course our Post graduate coordinator, Dr. Odu as well as the sub-dean, Dr Ogunwole and Prof. A.E. Salako. Thank you all.

I want to appreciate the technical crews' in the laboratory and the non-teaching staff. Mr Adelani (The Chief), Past. Odufoye (my friend), Taofik, Fabowale, Omotoso, Mrs. Joel, Mrs. Ngere; Seyi, Gboyega, Olaoluwa, Mrs. Olawuyi, Mr. Ajani and Elisabeth in the thesis room. Furthermore, I want to acknowledge the contributions of Ebenezer Awodutire, Oladejo Emmanuel, Moses and Mubarak who took good care of the experimental animals.

Special thanks to my fellow researchers: Adegoke Adebayo (Omo Oba), Mrs P. Komolafe, Ibukun Busari (IBK), Mrs. Daud Bukola , Mr. O. Yusuf and Mr. S. Omotosho, I enjoyed your company. I am highly indebted to Dr. Sosina Adedayo for his unquntifiable supports during the programme. I appreciate Bro Daranijo for providing solution to electricity problems during the thesis write-up. Special thanks to my pastors and co-labourers from Deeper Life Bible Church, The Gambia and Oluyole region for your prayers and advice. Pst. Odumosu, Pst. Oladapo, Pst. Adeniran, Pst. Olaniyan, Pst. Dan, Pst. Ayepola and Pst. Orimogunje, Pst. and Mummy Oyebola Pst. and Mummy Omojola, Pst.and Dr Ajibike for their support in prayers. Bro. Ola Epaphras and bro. Joshua Ezekiel of DLCF, Lead City University for their inestimable sacrifice.

Sincere thanks to my bossom friends: Pst. and Sister Ijadunola, Pastor and Sister Adeoshun; and Pst. and Sister Adedoja and Bro and sister Efunwole. Special thanks to Pst. and Prof. J. Oyundoyin who stir up my interest to register for the programme and stood with me till the end.

Special thanks to my parents for their assistance since my elementary school in the village to this level. My late father and late mother Mr. John Adewuyi and Mrs Sarah Adewuyi, you strove to give me education when and where it was not valued. My profound appreciation goes to my late brothers and Sister Mr. Elijah Banji Adewuyi, Mr. Joshua Adewuyi and Mrs. Felicia Agboola for your invaluable contributions to my education. I also appreciate the efforts of Pastor Kayode Adewuyi and his wife and Mrs. Esther Sanda and the husband, they are always there for me.

I wish to appreciate the prayer and the good will of Israel Adewuyi, Mrs. Beatrice Ajibade, Mr. Adewuyi Timothy (‘Uncle T’) and Elder Michael Adewuyi thank you all for your support. Special thanks to my in-laws: late Mrs. Funmilayo Ola-Oni who has always been supportive to us before her sudden death in UK. I appreciate the prayers of my mother-in-law Mrs. Deborah Oluwayemi and Mrs. Bose Ibitayo, Pst. Akinwande and Sis. Bose Onasanya thank you all.

My sincere appreciation goes to the former and present VC, University of The Gambia (UTG), late Professor Kkalili and Professor Faruq respectively for given me study leave with salary and other colleagues at the School of Agriculture (UTG) for their assistance in different ways.

I want to acknowledge my God-given fruits, Goodness Stephen Bamidele ('Pastor Good'), Mercy Priscilla Adenike (Baby 'Me') and Aquila Faithfulness Oluwadarasimi ('Bible man'), we all went through thick and thin together before the triumphant completion of this study. Finally, my heartfelt gratitude goes to my beautiful wife, Mary Monisola ('Maria'), actually it was God that brought you into my life; otherwise this programme would have been aborted long ago due to physical, financial and mental stress. Thanks for your love, endurance, sacrifice, prayers, understanding, patience and advice, I love you my darling wife.

ABSTRACT

Groundnut Haulm (GH) is a crop residue often used as a supplement for ruminant feeding in Nigeria especially during dry season. The use of GH as feedstuff is limited by bulkiness and high fibre content. Pelleting and urea-treatment have been widely used to improve the nutritive quality of high fibrous and bulky feedstuffs for ruminants. However, information on urea-treated GH and pelleted GH-based diets for ram in Nigeria is scanty. Therefore, nutritive value of urea-treated and pelleted GH-based diets for West African dwarf rams was evaluated.

Urea-Treated Groundnut Haulm-UTGH (100 kg GH + 4 kg urea/100L water) or Untreated GH (UGH) was mixed with concentrate at ratio 40:60 to formulate total mixed ration with or without pelleting. The four dietary treatments: UGH-Unpelleted (D1), UTGH-Unpelleted (D2), UGH-Pelleted (D3) and UTGH-Pelleted (D4) were assayed for Crude Protein-CP, Neutral Detergent Fibre-NDF and Acid Detergent Fibre-ADF using standard procedures. Total Gas Volume-TGV (mL), Methane (mL/200 mg DM) and Metabolisable Energy-ME (MJ/kg DM) were determined using *in vitro* gas production technique. Sixteen rams were allotted to the diets in a completely randomised design for 105 days to determine Dry Matter Intake-DMI (g/day), Daily Weight Gain-DWG (g/day), Feed Conversion Ratio-FCR, NH3-N (mg/100mL) and rumen Total Volatile Fatty Acid-TVFA (mmol/100mL) using standard procedures. In a seven-day metabolic study, Nitrogen Retention-NR, Crude Protein Digestibility-CPD and Crude Fibre Digestibility-CFD were determined using standard procedures. Data were analysed using descriptive statistics and ANOVA at α0.05.

The CP of 9.5±0.7% for D3 was lower than 11.9±0.2%, 11.4±1.0% and 11.3±0.6% in D1, D2 and D4, respectively. The NDF ranged from 54.5±1.1% (D1) to 56.9±1.3% (D2), while ADF of 39.9±1.0% (D1) was lower than 42.6±2.5% (D2), 42.3±1.6% (D3) and 41.5±1.4 (D4). The TGV of 27.1±0.1 for D2 was higher than 19.2±0.8, 16.2±1.2 and 12.4±1.2 for D3, D4 and D1, respectively. Methane and ME ranged from 6.0±0.02 (D1) to 15.0±1.20 (D2); and 4.9±0.3 (D2) to 5.6±0.4 (D4), respectively. The DMI of 578.9±20.2, 512.3±16.5, 474.0±17.2 and 450.0±12.5 for D3, D4, D1 and D2, respectively, were not significantly different. The highest DWG of 49.1±4.6 was recorded for rams on D4 and lowest of 18.7±8.5 for those on D1 indicating that urea-treatment and pelleting of diet enhanced growth performance in rams. The FCR ranged between 10.7±1.1 in D4 and 13.8±2.6 in D2. The NH3-N of 29.7±0.01 (D4), 28.7±0.01 (D3), 25.5±0.02 (D2) and 24.4±0.04 (D1) were similar. The highest TVFA of 258.4±20.1 was observed in rams allotted D3 and lowest of 244.9±8.8 in rams fed D1 showing that pelleting improved energy value of the diet. The NR of 80.7±6.4% (D2) and 79.8±4.4% (D1) were similar and significantly higher than 74.6±4.0% (D4) and 73.4±2.3% (D3). The CPD values of 83.4±0.02%, 83.1±0.01%, 78.1±0.03% and 77.9±0.10% in rams on D2, D1, D3 and D4, respectively, were not significantly different. The CFD ranged from 64.4±0.02% in D4 to 68.2±0.10% in D2.

Pelleting improved the nutritive value of groundnut haulm-based diets for West African dwarf rams. The growth performance of rams fed processed groundnut haulm-based diets was enhanced.

Keywords: Urea-treated haulm, Pelleted crop residue, Crude fibre digestibility, Total mixed ration

Word count: 495

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ABBREVIATIONS

i) ADENI: Agriculture Development in Nigeria

ii) AOAC: Association of Official Analytical Chemists

iii) AKY: Akinyele

iv) ASAE: The American Society of Association Executives

v) BDS: Bode Saadu

vi) ESGPIP: Ethiopia Sheep and Goat Productivity improvement Programme

vii) FAO: The Food and Agriculture Organization

viii) FEAST: Feed Assessment Tool

ix) FGD: Focus Group Discussion

x) GLSR: Gambia Livestock Sector Review

xi) ICRISAT:The International Crops Research Institute for the Semi-Arid Tropics

xii) ILRI:The International Livestock Research Institute

xiii) NRC: National Research Council

xiv) OGB: Ogbomoso

xv) PDI: Pellet Durability Index

xvi) SAS: Statistical Analysis Software

xvii) WAD: West African Dwarf

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The benefits entrenched in ruminant production are enormous but the optimal productivity of ruminant animals in the tropics is hampered mainly by the unavailability of year-round forage supply among other factors. Feed is known to constitute the highest percentage of production cost in animal husbandry. Feed and feeding problems at times lead to huge economic loss or total closedown of the entire livestock enterprise in many developing countries. Ruminant husbandry is a major economic endeavour in sub-Sahara Africa; it occupies a central position in the livelihood of rural households. Small ruminant rearing is a source of animal protein, helps in poverty reduction, and provides income to solve immediate needs (GLSR, 2010).

Ruminants naturally subsist on forage which can be provided by natural or established pasture. Pasture availability for livestock in the tropics is a serious constraint because of escalating population growth and the negative influence of changing climate. This may be ascribed to demographic pressure on the available land for residential building; and infrastructural and industrial development. Also, changing climate emanating from the emission of greenhouse gases contributes to global warming and is responsible for the loss of many plant species including those that are consumed by ruminants. It was projected that a 2.5°C increase inuniversal temperature may lead to a loss of about 30 species of plants and animals (IPCC, 2007). The implication is that forage will be negatively affected and this will adversely affect animal production and performance (Devendra and Leng, 2011).

In order for livestock farmers to mitigate the consequences of pasture shortage, they resorted to using alternative feedstuffs such as crop residues (CR) and agro-industrial by-products (AIBP). Crop residues are described as the plant materials that are left in the field after the target crops have been harvested. An example of a crop residue is groundnut haulm. Crop residue consists mainly of the stem and the leaves, but the leaves are usually higher of better nutritional value compared to the stems because of a lower proportion of fibre.

In the tropics, the small-scale ruminant holders depend largely on CR and AIBP as livestock feeds, especially in the dry season. Olafadehan and Adebayo (2016) reported that crop residues serve as an alternative feed resource for the period of the prolonged dry season. The utilisation of crop residues by ruminants is limited because they are fibrous, low in digestibility, and poorly degraded in the rumen. According to Leng (1990), CR are generally low in protein, high in fibre and of poor digestibility.

Among the strategies used in enhancing the utilisation of crop residues by livestock is legumes supplementation and urea treatment which increased their nitrogen content, digestibility, and overall utilisation by the animals (Cloete and Kritzler, 1984).

Groundnut (*Arachishypogaea* L.) haulm, a legume by-product is commonly used to supplement low protein roughages and crop residues in ruminant feeding. In a trial, Ososanya (2012) reported improved weight gain in WAD ram fed *Cynodon nlemfuensis* hay supplemented with up to 50% groundnut haulm during the dry season. Groundnut haulm consists of leaves, stems and at times leftover pods abandoned in the field after the groundnut is harvested. It is considered an important fodder for small ruminants, especially in ram fattening. It is a popular feed resource in some countries in the West Africa sub-region mostly in the dry season. In The Gambia, groundnut haulm is considered to be the most common traditional feed resource fed to the livestock on zero grazings for about nine months of the dry season (Asaolu *et al.,* 2010). In Nigeria, groundnut haulm was identified as a feed for livestock, particularly in thedry season when fresh and green grasses are scarce (ICRISAT, 2015).

1.2 Statement of the problem

Despite the high potential of groundnut haulm as a feed resource, its production is location bound, mainly restricted to savannah agro-ecological zones in Nigeria, and it is also bulky which poses a major problem in transporting it to different parts of the country where and when it may be needed. The dietary protein of groundnut haulm is also susceptible to loss to rumen microbes. According to the report by NRC (1985), dietary protein of forage can be lost to rumen microbes during ruminal degradation. Groundnut is usually harvested when the plant leaf is turning yellow as a result, leaf loss or shattering does occur in the field and on transit which reduces its nutritional value as reflected in low digestibility because of an increase in the stem to leaf ratio (Yasar and Mehmet, 2013).

Ignorance of nutritional importance of groundnut haulm as feed for livestock is still high among many agro-pastoralists and smallholder ruminant farmers in some parts of the tropics. Rehab *et al.* (2004) adduced that there is a poor understanding of the nutritional and economic importance of groundnut haulm as a ruminant diet among Egyptian livestock farmers FAO (2010) further explained that the low awareness of its nutritional value has subjected it to alternative uses such as organic manure and domestic biofuel.

Apart from legume supplementation, other strategies used in enhancing crop residues utilisation by livestock include physical, biological, and chemical treatments. Physical treatment, like chopping, shredding, grinding, and pelleting helps in particle size reduction and results in higher feed intake while chemical treatmentincreased fibre digestion, DMI, and daily body weight gain (Klopfenstein, 1978).

Pelleting of feed materials plays a significant role in feed utilisation by farm animals. It increases the bulk density of crop residues, thereby reducing the transportation cost and drudgery from an area of abundant production to wherever they are needed. Storage and handling loss of nutrients can be reduced by pelleting. In animal feeding, sorting of ingredients is common which reduces utilisation of feed. However, when feed is presented in form of a pellet, the animals are forced to consume the entire nutrients, thereby improving their performance. Pelleting, due to reduced particle size, increases total surface area, thereby increasing the rate of rumen microbial attachment for faster breakdown of fibre. Bowman and Firkins (1993) further reported that pelleting can increase the feed value of chemically treated forages.

Using urea in enhancing the nutritional quality of poor-quality livestock feed is gaining more acceptance among ruminant holders due to its availability, ease of application, and relative safety when compared to other chemical treatments like alkaline. The use of urea in nutrient enhancement has a multiplier effect on both treatment and nutrient supplementation. It improved intake of dry matter as well as digestibility. Urea treatment or supplementation help in the supply of ammonia nitrogen to the cell wall degrading microorganisms in the rumen for improved fibre utilisation by the ruminants (Bryant, 1973).

Pelleting has been widely used to reduce bulkiness in crop residues and urea treatment for improved rumen function. However, in Nigeria, information on urea-treated groundnut haulm pelleted feeds for ruminants is scanty.

1.3 Research questions /Hypothesis

Will urea treatment and pelleting improve the nutritive quality of groundnut haulm-based diets for West AfricanDwarf (WAD) rams?

Hypothesis: Performance of WAD rams fed urea treated and pelleted groundnut haulm based diets is better than those on unprocessed diets.

1.4 Aims and objectives

This study was aimed at evaluating location effects on the chemical composition of groundnut haulms and the nutritive value of urea-treated and pelleted groundnut haulm-based diets for (WAD) rams. Therefore, the study

a) Assessed groundnut production and haulms use by farmers in southern guinea savannah of Kwara and derived savannah of Oyo States respectively;
b) Evaluated location effects on the chemical composition of groundnut haulms;

c) Examined pellet quality, coefficient of preference, and chemical composition of urea treated or untreated groundnut haulm based-pelleted diets;

d) Determined *in vitro* gas production and rumen fermentation characteristics of urea treated groundnut haulms, and groundnut haulm-based pelleted diets;

e) Evaluated nutrient digestibility, nitrogen balance, growth performance, and cost-benefit of West African Dwarf rams fed urea treated groundnut haulm-based pelleted diets.

1.5 Justification of the study

Nigeria is reported to be the leading groundnut producer in West Africa,responsible for 51% of production in the West Africa sub-region (ICRISAT, 2015). If most of the haulms generated are processed into a readily available livestock feed like pellet, it will go a long way in alleviating problems associated with livestock feeding in Nigeria as well as the incessant herdsmen/farmers clashes.

Harvesting of groundnut is done when the leaf is turning yellow as a result leaf shattering in the field is common to groundnut plants. Leaf shattering of groundnut usually results in poor quality haulm since the leaf contains most of the nutrients. This also poses a digestibility challenge because of the high stem to leaf ratio. Urea treatment is known to have multiplier effects of treatment and ammonia nitrogen (NH_3-N) supplementation to the rumen. Therefore, it compensates for nutrient loss through the leaf and enhances the digestibility of high fibrous stem-dominated haulm.

The ammonia nitrogen (NH_3-N) of urea is non-protein nitrogen (NPN) which is more degradable by rumen microbes for utilisation than that of dietary protein nitrogen of the haulm. This makes the protein of the groundnut haulm escape ruminal degradation for digestion in the GIT and thus available to the animal for enhanced utilisation and performance. In essence, urea treatment increases groundnut haulm by-pass protein in the ruminant stomach.

Groundnut haulm, a crop residue, is bulky thereby making its transportation from the area of abundant production to other parts of the country where it may be needed difficult and available at an exorbitant price. Pelleting is known to increase the bulk density of crop residues, thereby making it easier and more portable to carry from one place to another at a relatively cheaper cost. Shrinkage and storage loss are also reduced or circumvented by pelleting, as the materials of the pellet are more compacted and of very low moisture content.

For some inherent reasons, livestock usually prefers certain feed ingredients to another during feeding which is called sorting. Sorting of ingredients usually leads to under-utilisation of feed nutrient and negatively affect the performance of the animal. Pelleting presents feed in a homogeneous form, thereby preventing sorting of ingredients by animals and thus improve their overall performance. Groundnut production is known to be location bound within agro-climatic zones and thus requires transportation at times to very far distant locations, hence making imperative and pelleting of a tremendous advantage.

1.6 Significance of the study

More people would have been interested in small ruminant production if there are readily available small ruminant feeds. This study was to benefit both the intended and present small ruminant farmers for higher production by developing a high nutritive groundnut haulm based-pellet feed which can be easily transported at cheaper cost with the added advantage of year-round availability both in the rural and urban areas.

1.7 Scope of the study

The study investigated the awareness of groundnut farmers of the haulms uses in the high production areas of Kwara and Oyo States and established their potentials as sources of the haulms for livestock in their immediate environment and beyond using a structured questionnaire.

The chemical composition of the haulms collected from the study areas was analysed before and after treatment with urea and processing into pellet form using standard techniques. The pellets' durability and hardness were tested while the acceptability of the feeds was examined from the coefficient of preference.

The outcome of urea treatment and pelleting on the nutritive value of the haulms and diets were further assessed by means of*in vitro* gas production methods for the evaluation of methane production, ME, SCFA, organic matter digestibility, and DM degradability. Rumen fermentation characteristics consisting of pH, ammonia-N (NH_3-N) production, microbial population, total volatile fatty acid, and proportions were studied as additional methods to examine the results of the processing on the nutritive quality of the diets.

A feeding trial that lasted 105 days was conducted to assess the growth performance of the rams using a complete randomised design in a 2 x 2 factorial arrangement. Parameters considered included daily feed intake, weight gain, and feed conversion ratio. Cost benefit analysis was examined to ascertain the profitability of feeding processed feed to rams. Nutrient digestibility was studied in a metabolic experiment. Parameters analysed included DM, OM, CP, CF, EE, ADF, ADL, NDF, cellulose and hemicellulose digestibility. Nitrogen balance and microbial protein synthesis were estimated and the effects of feed processing on nitrogen balance and protein yields by rumen microbes were obtained.

Data were analysed using the General Linear Model of ANOVA (SAS, 2003). Mean were separated by Duncans multiple range test and significance was declared at $P<0.05$.

1.8 Definition of terms

a) Crop residues: These are *plant* materials/parts remaining after harvesting, including leaves, stalks, roots.

b) Focus group discussion: It is a way to gather together people from similar backgrounds or experiences to discuss a specific topic of interest.

c) Groundnut haulms: Parts of groundnut plant mainly the leaves and vines with leftover pods collectively referred to as haulm

d) Participatory rural appraisal:It is a methodology used for interactive processes of social development and technique of learning from people, with the people, and by the people. It is for analyses, planning, monitoring, and evaluation.

e) Pellet: A small hardball, cylindrical or tube-shaped piece of any substance

f) Pellet durability index: It indicates the ability of the pellet to resist wearing away during storage and transport, it is calculated as the percentage of the weight of surviving pellets over the total weight of pellets when subjected to mechanical shaking.

CHAPTER TWO

LITERATURE REVIEW

2.1 Small ruminant production in Nigeria

Small ruminants form a major component of the livestock population in Nigeria. They comprise sheep and goats. The populations of goats, sheep, and cattle in Nigeria are about 34.5 million, 22.1 million, and 13.9 million respectively (RIM, 2010). They are reared throughout the agro-ecological zones of the country but are mostly domiciled in the north (ILCA, 1979). This might be due to the low incidence of trypanosomiasis in the drier region among other factors.

According to RIM (2010), the common breeds of sheep in Nigeria are the WAD, Yankasa, Uda, and Balami, whereas those of goats include WAD, Red Sokoto, or Maradi, and the Sahel breed. Nevertheless, there are certain cases of cross-bred among them. Generally, WAD is the primary breed in southern Nigeria perhaps due to their hardy and trypanotelerant nature as the humid climate is favourable for breeding of tse-tse fly that caries the trypanosome that causes trypanosomiasis.

In Nigeria, the major system of ruminant management is traditional where animals are allowed to move about to fend for themselves in addition to kitchen waste provided by their owners. There is no provision for housing and health care. The animals can be easily infected by diseases and are also exposed to adverse effects of tropical climate, stealing, poisoning, and road accident.

In the semi-intensive system, the animals graze on accessible forage during the day and are housed in the nighttime. The animals are supplemented in the morning and the evening, and prophylactic and curative medical care is provided. A Semi-intensive system is mostly practiced in urban areas (Umunna *et al.*, 2014). In an intensive system, animals are housed in a pen; feed like agro-industrial by-products or crop residues and water are provided *ad-libitum*. In this system, crop residues such as rice bran, cassava peels, and BDG are provided. There is adequate veterinary support to the animal and there is high performance and productivity by the animals. This system is peculiar to research institutions and commercial farms, especially in sheep fattening operations.

2.2 Benefits of small ruminant production

Farmers raise small ruminants for cash and household consumption. Small ruminants are relatively easy to own by resource-poor farmers, particularly women. The animals distribute the risks peculiar to agriculture because they reproduce faster than cattle. The livelihoods of poor rural households could be enhanced if they can increase the numbers of sheep, goats, and chickens and improve their productivity (GLSR, 2010). The increased numbers could be consumed to contribute to nutritional and food security, sold to generate income to solve immediate needs, or exchanged for larger livestock. For example, 8-10 small ruminants can be exchanged for a cow. Asides from their importance as means of foodstuff and livelihood, Kosgey *et al*. (2006) added benefits like a store of wealth, insurance against emergencies, and cultural and ceremonial purposes as benefits derivable from small ruminant production. Other products obtainable from small ruminants include milk, skin, and farmyard manure for soil fertility improvements. Sheep meat (mutton) and goat meat (chevon) are known to transcend beyond cultural or religious barriers (Peacock, 1998). Milk obtained from sheep is believed to prolong life, as Bulgarian shepherds that take a lot of sheep milk are known for living long.

2.3 Constraints of small ruminants' production

Different factors confronting small ruminant animals' production and productivity in the tropics have been identified by many workers. These challenges in most cases are similar especially in Sub-Sahara Africa. In a trial conducted in the Qugadogou region of Burkina Faso, it was reported that the major factors limiting small ruminant production are low levels of nutrition, high incidence of diseases (Parasites and infectious diseases), poor management, and genetic capacity of the indigenous breeds. This is similar to the finding of Abule (1998) that feed shortage is a key limiting reason in small ruminant production in tropical Africa. Devendra and Mcleroy (1992) further stressed that diseases form the major constraints in livestock management in many parts of the humid tropical region. The extensive system of management among smallholders is also responsible for low productivity in the tropics. Generally, animals under the extensive system are faced with problems of diseases, parasites, little output, and small body weight gain. Feed shortage during the prolonged dry season in sub-Sahara Africa is another constraint in small ruminant business.

In The Gambia, low access to veterinary services and inadequate government policy are among the challenges of small ruminant production (GLSR, 2010). The key factors militating against productivity and financial gains by the smallholder livestock farmers are limited access to veterinary services, inadequate feed resources, high cost of inputs, inadequate grazing land, and insufficient drinking water, the low genetic potential of the local breeds, lack of technical support and poor access to affordable credit (GLSR, 2010).

2.4 Crop Residues

2.4.1 Crop residues in ruminant feeding

Crop residues upon decayed and incorporated into the soil, improve soil fertility and serving as a major source of organic materials to the soil (Amuda, 2013), and help in stabilising the ecosystem of agriculture. Samra *et al.*, (2003) also reported that crop residues are good sources of minerals (nitrogen, phosphorous, sulphur and potassium. In many countries of Africa, cereal crops are widely cultivated with abundant of residues generated for feeding of livestock. In some communities in Nigeria, it is of mutual arrangement between the cattle herders and cereal crop farmers in which the crop farmers allowed their farm to be grazed by cattle after harvest, and in the process, the cattle also dropped their dungs which serves as farm yard or organic manure. Cereals crop residues, also described as low-quality roughages (Amuda, 2013), are important alternatives in ruminant feeding. Analysis of these crop residues roughages according to the procedures of Goering and Van Soest (1970) established that lignin, cellulose, and hemicellulose components of crop residues are high. Crop residues are low in digestibility, metabolisable energy, nitrogen, and mineral contents. They are bulky with high fibre, low protein, and poor degradability. The chemical nature of crop residues is subjective to the varieties of a plant (Kharat, 1974), the location, cultural practices and processing methods as well as treatments of the crops in question. Crop and wood residues are related feedstuffs used in livestock production but with a slight difference.

Cereal crops generated most of the crop residues and small quantities are obtained from sugar cane, cocoa, banana, cotton, cassava, and haulms from cowpea and groundnut. According to (Menke and Steingass, 1988), Crop residues are poor in nutritive quality. Due to the presence of cell wall carbohydrates-associated polymer called lignin in crop residues, their digestibility is generally low. The coarse nature and low nutrient value of crop residues limit the activity of rumen microbes, reduce digesta clearance, and thereby lowers voluntary intake (Blummel and Becker, 1997).

The prospects of crop residue as a feed is not fully explored in many parts of the world. Amuda (2013) opined that research reawakening is needed in this area. Hence, the idea of blending ruminant production with accessible feedstuff (Amuda, 2013) has thus provoked more works into utilisation of crop residues in most developing countries. In a crop-livestock production system, sheep and goats can make better use of by-products of agriculture, and farmers that produce crops only can utilise their residues for improvement of soil fertility (Babayemi *et al*., 2014).

Ruminants generally feed on the remains of crops after harvesting. Agricultural by-products and arable weeds are not maximally utilized when the ruminant component is missing in the system. Roughages are excellent feed for ruminant livestock production (Wora-Anu *et al*., 2000).

Low digestibility, deficient crude protein, and mineral contents are common characteristics of crop residues. However, low awareness of crop residues as a feed resource among some small ruminants' holders, transportation challenges due to bulkiness, seasonality of production, and alternative uses are among the constraints facing the utilisation of crop residues for livestock (Sansoucy and Emery, 1982).

Legume crop residues, like cowpeas and groundnuts, supplementation of high-fibre, low digestible crop residues can improve crop residue utilisation. Butterworth and Mosi (1986) also corroborated increased digestibility of low-quality roughages upon protein supplementation. Supplementing natural pasture with groundnut hay for lactating Tswana does increase milk production, daily gain, and final weaning weights of the mother and kids (Macala *et al*., 1996).

2.5.0 Groundnut production and haulm utilisation as a livestock feed

Groundnut (*Arachis hypogaea* L) is planted worldwide mainly for its oil and seed. The developing countries are responsible for over 95% of global groundnut output ((Freeman *et al*., 1999). In Nigeria, it was a leading export crop in 1967 during the time of groundnut pyramids in Kano (ADENI, 2003). The crop is grown for its nuts which are eaten raw, boiled, roasted, or processed into snacks or butter.

The major agro-ecological zones of groundnut production in Nigeria are the drier or savannah regions of the country covering the middle belt and northern states like Kwara, Niger, Kano, Sokoto, Bauchi, etc of which is soil is sandy, poor in fertility, liable to erosion and low in the water holding capacity (ICRISAT, 2015).

Challenges facing groundnut production in Nigeria range from drought, diseases, and poor soil fertility among others. Groundnut production in Nigeria is mainly rainfed and as a result, farmers do experience crop failures due to insufficient rainfall or distribution problems. Rosette diseases and leaf spot are among major diseases affecting groundnut production, apart from the aflatoxin problem which poses health problems to man and animals through groundnut consumption.

To enhance groundnut farmers' optimal return, an improved cultivar of groundnut with a high economic value called SAMNUT was released by ICRISAT. It has multiple advantages of higher kernel size, disease-resistant, and high haulm yield ability (ICRISAT, 2015).

Due to traditional farm management, poor soil conditions, drought, diseases, and other constraints, the productivity of groundnut in Africa is about 929 kg/ha compared to 3632kg/ha in America (FAOSTAT, 2014). Depending on varieties, groundnut haulm can be as twice as the quantity of groundnut pod, which is of better advantage in the varieties grown for forage as feed for livestock. In Africa and Asia, dual-purpose groundnuts cultivars that combine high haulm yield with good pod production have been developed and released (Etela *et al*., 2011). In America, perennial groundnut (*Arachis glabrata*), is grown mainly for forage purposes (Hill, 2002).

2.5.1 Groundnut haulms as a livestock feed

Centuries ago, groundnut is grown primarily for oil and nut; the vegetative parts are left in the field to decay and help in the improvement of soil fertility. As the search for alternative feed resources progresses, the vegetative part of groundnut, mainly the leaves and vines with leftover pods collectively referred to as haulm, has become a popular feed resource in the livestock industry. The haulm is known to be acceptable by livestock. Liao and Holbrook (2007) added that groundnut haulms are more palatable than many other fodders. Groundnut haulm can serve as a supplement or be fed alone to the animals (Etela *et al*., 2011). It can as well be given to livestock fresh, dry, or in ensiled form (Hill, 2002). Groundnut haulms are relished by animals due to their relatively high protein value (Liao and Holbrook, 2007). According to Singh and Diwakar (1993), the protein and cell wall carbohydrate contents of groundnut haulm ranged from 5-15 % and 38-45% respectively. Groundnut haulm can be included up to 500 – 800 g/kg in the diet of sheep for optimum weight gain and efficient nutrient utilisation during the dry season (Ososanya, 2012). The protein value of groundnut haulm is higher than maize stover but possesses similar energy content. Groundnut is the largest crop produced in The Gambia and the haulm obtained is the most available feed resource for the small ruminants during the nine months of dry period in the urban and peri-urban areas (Asaolu *et al*., 2010). Groundnut hay is extensively used for livestock in India (NDDB, 2012). In milk-producing groundnut-based crop-livestock systems, groundnut hay was a major feedstuff (Devi *et al*., 2000).

2.5.2 Groundnut haulm in sheep feeding

Small ruminants are fed with groundnut haulms more than other species of livestock, as a result, in tropical countries of the world more research works are directed at the determination of the best feeding strategy in using groundnut haulm as a supplement for small ruminants on poor feeding regimes (Etela *et al*., 2011). In Nigeria, dual-purpose groundnut haulm cultivars fed solely to sheep have been reported to result in a good performance in terms of intake, weight gain, digestibility, and nitrogen utilisation. Groundnut haulm has been supplemented up to 40% in growing lambs feeding with economic benefits but the maximum daily weight gain was recorded in 20% supplementation (Durga *et al*., 1986). Ayantunde *et al*. (2007) reported increased daily weight gain though not up to profit level in Peul Oudah rams fed bush hay *ad libitum* and supplemented with up to 450 g/d groundnuts in Niger however recommended the addition of energy concentrate like millet bran for profitable performance. Abdou *et al.* (2011) also corroborated this author that groundnut haulm can be supplemented in the diets of male lambs up to 400g/d when there is abundant feed and energy source like millet bran for satisfactory performance. When the performance of lambs on different legume hays was assessed in the USA, it was observed that groundnut hay had the best performance result (Foster *etal*., 2009). It is the major feed stuff in most of the small ruminant markets in West Africa where it is used in sheep fattening operation and also fed to the animals on regular basis before they are sold off.

2.5.3 Constraints to using groundnut haulm as a feedstuff for livestock

Groundnut haulm, like any other crop residues, is bulky which poses difficulty in its transportation from the areas of abundance to other parts of the country where they may be needed and are not available. Bulkiness is known to be a challenge in the utilisation of crop residue as a livestock feed because of high cost of transportation. Also, groundnut is harvested when the plant is fully matured and the leaf turning yellow (Yasar and Mehemet, 2013). At this stage, there is problem of leaf-fall or shattering of the haulm especially during harvesting which normally leads to the high fibre content of the haulm occasioned from increased stem: leaf ratio because of high fibre portion of the dominating stem. Hill (2002) reported that leaf loss lowers the leaf: stem ratio thus the nutritive quality in terms of low digestibility and nitrogen content of the haulm. In addition, groundnut haulm protein can be lost to rumen microbes as it is applicable to any other legumes if it is not protected or fed along with other protein source that is easier to access by the ruminal microorganisms. Among the improvement strategies for utilisation of bulky and low digestible feed materials are physical and chemical treatments like pelleting and urea treatment respectively.

2.6 Roles of treatment in improving the nutritive value of feed

Physico-chemical and biological treatment methods have been adopted to improve the digestibility and intake of fibrous plant materials (Sansoucy, 1995). Chopping, shredding, grinding, and pelleting are forms of physical treatment in improving the nutritive value of forage for ruminants out of which only grinding is known to increase voluntary intake (FAO, 2010). Beardsley (1964) reported that reduction of particle size can result in the faster flow of degraded fibre materials from the rumen to hinder digestive tracts, and reduce retention time and digestibility. The low retention time in the stomach is compensated for by increased voluntary intake and resulted in higher digestible energy for the animal. Treatment helps in overcoming digestibility hurdles by reducing the refractory fibre size and exposing the roughage to rumen microbial attachment and degradation (Lam *et al.,* 1992). Increased digestibility due to particle size reduction stimulates voluntary intake and aids the faster movement of digesta to the lower alimentary canal (Lechner-Doll *et al*., 1995). Wittenberg and Boadi(2001) reported a decrease in methane formation as a result of grinding and pelleting which would likely translate into higher volatile fatty acids for the animals. For optimum performance of the animals, treatment alone is not sufficient since fibrous forage is poor in key nutrients like nitrogen, therefore supplementation with degradable nutrients like nitrogen is necessary for increased activity of ruminal cellulolytic microorganisms responsible for energy and protein supply to the ruminants (Preston and Leng, 1987; Leng 1990).

2.6.1 Urea treatment of crop residues

Crop residue is abundant in the tropics thus making it a possible sustainable and practicable alternative ruminant feed resource. However, harvested matured crops are usually highly lignified. Earlier studies have proved that chemical treatment increased fibre digestibility as well as dry matter intake, average daily gain, and feed conversion ratio (Klopfenstein, 1978). Application of chemical treatment to crop residues with NaOH is reported to constitute environmental pollution as a result of residual chemicals washed into the environment apart from the loss of soluble fibres (Fahey *et al*., 1993).

To avoid or minimise the inherent danger of environmental pollution that goes with caustic soda or sodium hydroxide (NaOH) treatment, ammonia (NH_3) was a better alternative. Urea treatment or ammoniation of crop residues is more appropriate among the livestock farmers in the developing countries because urea is available, easy to handle and is also familiar to the farmers. Furthermore, urea treatment is preferred to NaOH because its nitrogen is not of amino acid origin and therefore can be easily transferred across the microbe's cell membrane for protein synthesis (Klopfenstein, 1978). It also has the additional advantage of enhancing feed intake as well as digestibility (Morris and Mowat, 1980). Fahey *et al*. (1993) reported improved dry matter digestibility and intake with NH_3 treated crop residue over the untreated while Sundstøl and Coxworth (1984) further added that ammonia treatment reduced supplemental protein associated with residue treated feeds. Paterson *et al*. (1981), in addition, observed increased DM digestibility of up to 10% and dry matter intake in lamb fed 2% NH_3 treated cornstalks. According to Zorilla-Rios *et al*. (1985), 3.5% NH_3 treated wheat straw showed enhanced crude protein and *in vitro* dry matter digestibility. Nevertheless, NDF, ADF, and hemicellulose were not affected. Increased dry matter intake was related to ease of mechanical breakdown due to ammoniation and a faster flow rate of materials in GIT (Allen and Mertens, 1987).

2.7 Effects of pelleting on feed utilisation

Physical processing of crop residues has improvement on their nutritive value and utilisation by livestock. The process of fibre degradation in the rumen commences with the attachment of the rumen microbes to the ingested feed materials. Consequently, physical processes like grinding and pelleting which crush cell walls and reduces particle size create larger surface areas for attack and attachment by ruminal microorganisms. Hooper and Welch (1985) reported that grinding enhanced particle density and results in faster movement of ingested feed materials within the GIT and ultimately, according to Minson (1990), enhanced voluntary intake but reduced the retention of materials in the rumen. Usually, reduction in rumen retention time decreased digestibility but Van der Honing (1975) argued that increased DMI and better efficiency of feed utilisation due to reduced particle size will compensate for lower digestibility. On the contrary, Shain *et al*. (1996) reported similar DMI when animals were fed alfalfa or straw with reduced particle sizes but confirmed the results of Shreck *et al*. (2011) that chopped corn stover improved average daily gain and efficiencies.

Several authors had reported pelleting to increase dry matter intake vis a vis non-pellet feeds (Beardsley, 1964; Campling and Freer, 1966; Coleman *et al*., 1978; Obasa *et al.,* 2017) but digestibility, according to Greenhalgh and Reid (1973), was reduced by 10% when pelleted roughage was compared to normal physical form. Minson and Milford (1968) also reported a 6.8% reduction in digestibility for pelleted ration. In poultry feeding, pellet feeds have been widely preferred to the mash because of diverse advantages ranging from ease of transportation, prevention of ingredient sorting, reduction of wastage by the animals, and better growth performance than unpelleted (Van, 2005).

2.7.1 Pellet quality indices

Two important physical qualities of a pellet are hardness and durability index. The hardness of a pellet refers to its ability to resist and withstand direct pressure, it can be determined directly using a pellet hardness tester, which is calibrated in Newton (N). The harder the pellet, the better the quality as this will reduce pellet breaking and turning into fines when exposed to direct pressure in the store or at the point of feeding the animals, and it also affects its keeping quality, the harder the pellet the longer the shelf life or storability. The other important quality of a pellet is the durability indexwhich describes its ability to withstand pressure resulting from mechanical handling and transportation without crumbling which can lead to wastage on transit or higher production of fines at feeding. Pellet durability index can be measured by tumbling box test, Holman Pellet Tester or ASAE S269.3, a predictor of pellet fine (ASAE, 1987). However, farmers are more interested in a direct measurement of the fines at the feeders than at the mill for the higher the fines at the feeders, the greater the feed wastage and loss.

2.8 Acceptability of feed

Acceptability is usually interchanged or mostly used in place of palatability. Acceptability is described as the attraction of feedstuff to the animal as determined by the factors of the feed and the environment. Palatability on the other hand is known as the fondness with which a plant part or animal feed is consumed by animals. It can also be explained as the factors of the feed that determine its absolute attractiveness to an animal. It is a relative term that depends on the condition in which the feed is presented to the animal.

Acceptability has a direct relationship with the amount of protein, energy, minerals, ether extract, and water content, while it has an inverse relationship with roughage lignification and fibre amount in a feedstuff. Acceptability in addition is subjective to the physical properties and structure of the feed in the grasses, for example, selection by both cattle and sheep is negatively correlated with leaf strength. Plant structure may influence acceptability by affecting the accessibility of leaf top by grazing animals (Olanite *et al.,* 2011).

Free choice intake and acceptability study is a quick assessment of the physical quality of a feed. Coefficient of Preference (CoP) is used in calculating the acceptability and nutritional capacity of forage or feed. Recently, the cafeteria method has been used to assess the acceptability of some forage (Bamikole *et al.,* 2004; Babayemi *et al.*, 2006). Acceptability of forage is controlled by some factors which include physical form, harvesting, and metabolic feedback, and anti-nutritional factors.

2.9 Rumen microbes, fermentation characteristics, and pH

2.9.1 Rumen microbial ecosystem

Herbivores live primarily on forage or plant materials. They cannot digest the roughage fibre themselves; therefore they form a symbiotic relationship with rumen microorganisms that produce enzymes capable of hydrolysing plant cell wall carbohydrates, like hemicellulose and cellulose, to produce energy for themselves and the host animals. The rumen microbes survive mainly in an oxygen-free environment in the rumen of the ruminants (Clarke *et al*., 2011); thus natural ruminal microbes are mostly anaerobes. They are classified as bacteria, fungi, protozoa, archaea (methanogens), and bacteriophages. The ruminal dry matter, temperature, pH (highly variable) ranged between 10–13%, 38-41 °C, and 5.5 - 6.9, respectively. The pH of the rumen is maintained through the flow of saliva produced during rumination, hence the high buffering ability of the ruminal content (Dehority, 2003). The population of the three main microorganisms in the rumen according to Williams and Coleman (1997) are 10^{10}-10^{11} per ml, 10^{3}-10^{6} per ml, and 10^{4}-10^{6} per ml for bacteria, fungi, and protozoa, respectively.

Bacteria play the most important roles in rumen fibre degradation probably due to their ability to survive floating in the rumen fluids contents, attached to rumen wall, a symbiotic link with fungi or protozoa, and high-density attachment to feed particles (Mitsumori and Minnato, 1997). Based on their activities in the rumen, they can be grouped as fibre degrading bacteria, starch or sugar digesters, or lactic acid users.

Fungi are the least populous of the ruminal microbial consortia (Rezaeian *et al*., 2004) but are considered to have the highest efficiency of fibre degradability (Akin *et al*., 1988). They produce different kinds of enzymes that digest cellulose (Barichievich and Calza, 1990), hemicellulose (Novotna *et al*., 2010), and solubilise lignin (Akin and Borneman, 1990).

Rumen protozoa are motile with the aid of flagella or cilia and are dependent. Williams and Coleman (1997) reported that they feed on bacteria, and digest carbohydrates, fats, and protein. Further, they are known to digest fibre and produce acetate, propionate and butyrate like bacteria. They can make use of starch and solubilise sugars for energy production (Williams, 1979) as well as helping in nitrogen recycling in the rumen.

Methanogens or archaea form a symbiotic relationship with bacteria and protozoa in the rumen. They produce CH_4 from H_2 and CO_2 produced by bacteria, protozoa, or fungi and ATP is generated through the process (Lange *et al*., 2005). The activities of methanogens prevent the accumulation of H_2 produced during fermentation (Wolin and Miller, 1988), reduce H_2 partial pressure in the rumen (Lange *et al*., 2005), and generate ATP for the donors (Wolin and Miller, 1988).

Bacteriophages are necessarily pathogens in the rumen for their roles in lysing rumen bacteria cells and making their protein available in form of amino acids to their host and controlling the population of methane-producing bacteria.

The interaction of the rumen microbes is necessary for complete degradation of feed ingested by the herbivores. Certain microbes' breakdown complex feed materials into simpler forms like sugars, which are transported and fermented by others to produce vitamins and short-chain fatty acids Bryant (1973), and others split $CO(NH_2)_2$ into CO_2 and NH_3 that enters the rumen through saliva, blood or feed (McAllister *et al*., 1994). The NH_3 provides amino acid in the rumen bacteria and CO_2 as an energy source. The methanogens are considered to contribute to greenhouse gas and lower energy value of feeds (Moss *et al*., 2000), but they play vital roles in reducing the volume of H_2 in the rumen; otherwise, the fermentation process will not proceed as a result of pressure from accumulated H_2.

Pelleting is a particle size reduction process that enhances fungi hyphae penetration and provides more surface areas for bacteria attachment to the feed particles for improved activities and fibre degradation. Furthermore, urea treatment is a rumen degradable protein source to rumen microbes which helps to improve microbial protein synthesis for increased activities and fibre degradation by breaking of the lignin-cellulose matrix of the cell wall.

2.10 Feed processing and volatile fatty acids (VFA)

Volatile fatty acids are the products of carbohydrates degradation mainly by rumen microbes. They are short-chain fatty acids present in anions form due to the relatively stable pH of the rumen and include acetate, propionate, and butyrate, which are the most important in ruminant feeding with acetate having the highest proportion. They are the primary source of energy for ruminants. According to Bergman (1990), VFA provides 80% of maintenance energy for ruminants. The range of the molar ratio of acetate to propionate to butyrate is approximately 75: 15: 10 to 40: 40: 20, respectively (Bergman, 1990). Acetate is the essential building block for milk fat, while Herdt (1988) established that propionate is the main source of gluconeogenesis in the liver.

The additional nutritional benefit of VFAs is in their ability to improve Na and fluid absorption in the intestines. Imbalance acetate: propionate will lead to heat increment because a reducing factor from propionate is needed to convert excess acetate to fat stored in the body or adipose tissue (Leng, 1990).

Feed processing like pelleting, which is a particle size reduction enhances microbial activities by providing large surface areas for cellulose digestive enzymes of bacteria and easy penetration of fungi hyphae. Further, urea treatment supplies degradable protein to rumen microbes to synthesise their amino acids and help in improving fibre degradation. All these enhance the VFA production capacity of the rumen microbes and increase energy for the animals.

2.11 Urea ammoniation and methane production

Methane production contribute to greenhouse gas emission also considered as a loss of dietary energy in ruminants (Morris *et al*., 2000). Methanogenesis has been reported to be high in ruminant fed high fermentable metabolisable energy and low rumen degradable protein diets (Johnson and Johnson, 1995). One method of mitigation of the emission of methane, which is a greenhouse gas, is strategic urea supplementation of ruminant diets. Supplementing urea, a cheap rumen degradable protein at 1 %, Cottle (1991) or up to 6 % (Currier *et al*., 2004) dry matter in ruminant diets reduces methanogenesis. The two authors maintained that rumen degradable protein sources like urea will easily improve microbial protein synthesis and reduce surplus carbohydrate from fermentable metabolisable energy feed materials that end in methane production.

2.12 Rumen pH

Rumen pH affects microbial populations, ratios, and activities in ruminants. When the pH falls below 5.5, certain protozoa are known to be uncomfortable. Ruminal pH is usually higher before the morning feeding since the animals normally ruminate in the evening. The pH usually decreases after feeding a highly fermentable carbohydrates feed (Ghorbani *et al*., 2002). The digestion of fibrous materials occurs between 6.0-6.2 pH, whereas higher acidic conditions of pH of 5.2-5.6 favoured digestion of starch

(Saricicek and Ozel, 2010). Orskov and Ryle (1990), reported that rumen pH is lowered to the minimum between 2-6 hours after feeding based on the diet composition, feed consumption rate, and the retention time in the rumen contents in the rumen. The ruminal pH range of 6.0-7.0 is the optimal requirement for most rumen microbes (John, 2005).

Factors controlling rumen pH, according to Owens *et al*. (1998) include the relative concentration of bases, acids, and buffers. The major base in the rumen is NH_3, lactate being the primary acid, and bicarbonate and phosphate from saliva are the major buffers. Ruminal pH is regulated or buffered by saliva that is produced during the rumination process.

The fermentation process in the rumen resulted in volatile fatty acids production and the acids are absorbed through the rumen wall, otherwise, the buildup will reduce the pH value and results in acidosis. Acidosis is a prominent digestive problem in commercial dairy production, with prevalence diagnosed using rumenocentesis ranging between 12 and 30% throughout lactation (Krause and Oetzel, 2006). Most of the earlier studies on ruminal acidosis were on dietary factors like particle size, distribution, diet fermentability, and microbial influences. In contrast, the absorption and clearance of acid from the rumen has received little attention. Allen (1997) established that approximately 53% of protons produced during anaerobic fermentation leave the rumen through the absorption of VFA through the ruminal wall, implying that absorptive metabolism may have a strong effect on the regulation of ruminal pH. Past research has demonstrated that diet can affect the absorptive metabolism in ruminal tissue. Diets containing a higher percentage of concentrate have previously been established to increase VFA disappearance from the rumen by absorption (Gäbel *et al*., 1991) and the net absorption rate in *vitro* (Uppal *et al*., 2003). A conducive rumen environment as presented in the normal pH, is required for optimal performance of rumen microbes.

2.13 Urea treatment, pelleting, and nutrient digestibility

Digestibility and chemical components of a diet are among the parameters used in the assessment of its nutritive quality. Strategies to enhance the physical composition or digestibility of a feedstuff will eventually improve its nutritive value. Urea treatment has been reported by many researchers to possess both treatment and supplementation advantages for its efficacy to improve fibre digestibility and addition of NH_3-N for microbial growth (Sundstøl *et al.*, 1978; Abate and Melaku, 2009; Schiere and Ibrahim, 1989). Bryant (1973) reported preference of cellulolytic bacteria for NH_3-N which, according to Russell *et al*. (1990) was due to their deficiency in mechanism needed for transportation of NH_3-N across their cell membrane into the cytoplasm.Urea-molasses, as a supplement for sheep,has proved to improve rumen NH_3-N fermentation as well as daily gain (Sudana and Leng 1985), and dry-mater intake and digestibility (Ibrahim, 1989). Pelleting, a particle reduction size processing method, may reduce digestibility because of the fast rate of clearance in the ruminant's digestive tracts (Campling and Freer, 1966). Pelleting also enhances fungi hyphae penetration during colonization which is the first process of fibre degradation by the microbes (Phillips and Gordon 1991). Combination of pelleting and urea treatment enhances digestibility and fibre utilisation by the animals (Thiruchittampalam and Jayarisuya, 1978).

2.14 *In vitro* gas production

The gas production technique is generally adopted for the evaluation of the nutritional value of a diet. Lately, the growing attention in maximising the effective use of forage-based diets has increased the utilisation of gas production methods because of the benefit of exploring fermentation kinetics. Gas production assessment offers beneficial facts on digestion kinetics of soluble and insoluble parts of feed material.

In developing countries, the *in vitro* gas technique based on syringes seem to be the most appropriate because of the simplicity of its procedure (Menke *et al.*, 1979; Blümmel *et al.*, 1997). A gas production technique is based on the presence of fermentation of fermentable products. In this method, the kinetics of fermentation can be evaluated on a small portion of samples and many samples can be studied at a time.

Furthermore, Makkar *et al.* (1995) reported that the *in vitro* gas technique can effectively monitor nutrient-antinutritional and antinutritional-nutrient interactions.

This technique does not involve complex equipment or the use of many animals (just one or if possible two fistulated animals are needed) and helps in the choice of feedstuffs with the additional advantage of not depend only on the DMD but also on the efficiency of MCP production.

In the technique of Menke *et al.* (1979), fermentations are carried out in 100 ml volume calibrated glass syringes holding feed samples and buffered rumen fluid. The gas liberated, on incubation of 200 mg feedstuffs, dry matter after 24 h of incubation with the levels of other chemical added is adopted to estimate digestibility of OM and ME assessed *in vivo*.

Blümmel *et al*. (1997) asserted that gases liberated through rumen fermentation are of no nutritional advantage to the livestock, but gas production techniques are used in evaluation of nutritional quality of a feed. TheIVGP method (Menke and Steingass, 1988) is used generally in livestock nutrition for feedstuff assessment and to evaluate the kinetics of microbial fermentation pathway in the gastrointestinal tract. Krishnamoorthy *et al*. (1995) also opined that *in vitro* gas production method could be used in assessing metabolisable energy (ME) in tropical feedstuffs, because other techniques take a longer time and are expensive. Getachew *et al.* (2004) observed that gas production in straw consists of two phases; one being the soluble phase (quick gas production) from the soluble portion of the straw and the other from the insoluble fibrous portion of cell-wall. In addition, Menke and Steingass (1988) designated the third phase of gas production, as being contributed by microbial turnover.

2.15 Urea fermentation and nitrogen balance

Nitrogen balance describes the fraction of nitrogen or protein available for utilisation by an animal which represents the quantity that is retained after faecal and urinary loss. One of the sources of protein to the rumen microbes in the diet, which is attacked in the rumen for microbial cell synthesis and growth. In the presence of non-protein nitrogen (NPN) substances like urea, which is also rumen degradable protein, the microbes spare the dietary protein and degrade the urea to generate NH_3-N, which they fix for their protein synthesis. The microbial protein is made available by the death and/or defaunation of the rumen microbes into the lower digestive tracts as a protein source to their host. Chumpawadee *et al*. (2006) reported that up to 80% of ruminant amino acids are obtained from microbial protein.

Provision of NPN, for example, urea, has been reported to be one of the most efficient strategies of improving the supply of microbial protein to the ruminants. Blummel *et al*. (1999) added that it is economical. Several authors have reported linear effects of rumen degradable protein, like urea, on MCP yield, and improvement on the performance of the animals in terms of feed intake, rumen fermentation, organic matter, and cellulose and hemicellulose digestibility. Urea is used extensively in a dairy cow. Russell *et al*. (1992) opined that urea can be successfully used as a part of supplemental protein for dairy cows, and Hannon and Trenkle (1990) further that it can be fed exclusively as a source of protein to the same animal, while Gould (1969) reported that exotic lactating cows perform equally well when urea contributes up to 12% rumen degradable protein of the ration.

2.16 Urea treatment, pelleting, and growth performance

Urea treatment has been reported to improve forage digestibility and also as a source of non-protein nitrogen in livestock feeding (ESGPIP, 2007). Several authors reported an increase in dry matter intake and efficiency of feed utililisation when animals are fed pelleted diets compared to unpelleted (Campling and Freer, 1966; Coleman *et al*., 1978). Feeding urea treated and pellet feeds have been reported to improve growth performance in livestock. Olafadehan (2016) reported a higher gain in Red Sokoto goats fed urea treated sorghum tops when compared to untreated. Bonfante *et al*. (2016)recorded a higher intake of feed for heifers on pelleted diets in comparison with unpelleted diets.

2.17 Urea ammoniation and microbial protein synthesis

In ruminant nutrition, microbial protein is the major contributor of metabolisable protein to the host animal. Hristov and Broderick (1996) reported that microbial proteins can be responsible for up to 90% of the protein reaching the small intestine, even though substantial part of microbial protein synthesised is degradable in the rumen. A diet with higher ruminal degradable protein results in higher bacterial nitrogen flow into the duodenum (Volden, 1999). The availability of adequate readily fermentable carbohydrates and ruminally degradable protein in the diet as established by Leupp *et al.* (2009) are very cardinal in ruminant feeding in that they enhance the efficiency of microbial protein synthesis. Feeding a urea ammoniated diet to animals is a source of readily degradable non-protein nitrogen to the rumen microbes, which can result in higher microbial protein yield in the presence of optimal fermentable energy.

2.18 Participatory Rural Appraisal (PRA)

Participatory rural appraisal, according to Duku *et al. (*2010), comprises a set of techniques aimed at sharing knowledge between local people and outsiders. PRA offers a robust discussion among the participant, with a view of charting a progressive way forward or finding a solution to a common problem or issue. Unlike the rapid rural appraisal, according to Chah *et al.* (2013), PRA was defined as a systematic but semi-structured study, carried out in the field by a multi-disciplinary team over a short period ranging from 3 days to 3 wks based on information collected in advance from a particular source as to generate working hypothesis for subsequent actions (Chah *et al.*, 2013)

PRA operated with the following principles as outlined by Babayemi *et al.* (2014) and Amole and Ayantunde (2016) as Participatory, Flexible, Teamwork, Optimal ignorance and systematic. Based on the above assumptions, PRA consists of two components; the Focus Group Discussion (FGD) and structured questionnaire (Appendix 1).

A participatory rural appraisal is an opportunity for a robust discussion or interaction among the various stakeholders with a view of proffering solutions to a specific or group of challenges. It allows researchers to learn from the target people about situations confronting them (Babayemi *et al.*, 2014). PRA makes programmes and projects to be farmers-centered rather than the researcher's mere opinion. PRA generates grassroots information that helps in developing an intervention strategy that address the respondents need in a balanced and comprehensive manner because of their involvement in the original identification of their challenges. This give the FGD a relative higher advantage of intervention that was built on it to be more acceptable among the concerned group than those that was planned and imposed on the people.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study one: Groundnut production and haulm use in Morro (LGA), Kwara State, and Ogbomoso (LGA) of Oyo State

3.1.1 Description of the study areas: Ogbomoso LGAs are located within the derived Guinea savannah of Oyo State while Morro LGA on the other hand falls within the southern Guinea savannah of Kwara State (Figure 3.1). The two locations are conducive for groundnut production due to their relatively high temperature and the well-drained sandy nature of their soil. Ogbomoso consists of Ogbomoso North and Ogbomoso South local governments combined and managed as one agricultural extension zone of Oyo State Agricultural Development Programme. Ogbomoso LGAs fall within longitude 4º14'42.66"E and latitude 8º8'31.7940"N and Morro LGA are within longitude 4º47'00"E and latitude 9º56'00"N.

3.1.2 Experimental materials

Materials used in this study digital Geographical Programme System (GPS) and structured questionnaire.

3.1.3 Sampling process:

The two locations were purposively selected because of their reputation for high groundnut production. The sampling method used was participatory rural appraisal (PRA) which consists of focus group discussion (FGD) and administration of the individual questionnaire. Six villages were purposefully selected from the two study locations based on their groundnut production capacities. Respondents were selected using a snow ball approach with the help of the agriculture officers in charge of the respective studied locations as the key informants who also played a key role in FGD. The three villages from Morro LGA were Awesu, Sharanga, and Bode Saadu; and Abogunde, Iwofin, and Agriculture Farm Settlement from Ogbomoso LGA

3.1.4 Focus group discussion (FGD) involves the interactive generation of ideas on groundnut production, marketing, small ruminant kept, need assessment, and possible solutions. Three FGD were held in Morro LGA and two in Ogbomoso LGA with a minimum of about 15 participants in each FGD as recommended by Feed Assessment Tool (Feast) of International Livestock Research Institute (ILRI) after which structured questionnaires were administered among the selected participants.

3.1.5 Structured questionnaire: A total of sixty farmers were randomly selected for interview. Thirty respondents from Morro LGA and thirty from Ogbomoso LGA using a structured questionnaire to obtain relevant information.

3.1.6 Data collection:

Data collected were on respondents' socioeconomic characteristics, farm size, groundnut yield, small ruminant kept, haulm uses, sources of capital, labour, constraints and solutions, and others as contained in a structured questionnaire in

Appendix 1. Groundnut (SAMNUT-21) haulm yield was estimated as twice the quantity of pods (ICRISAT, 2015).

3.1.7 Data analysis

Data obtained from the individual questionnaire were analysed using descriptive statistics while simple ranking, pair-wise ranking, and matrix scoring were employed for FGD analysis.

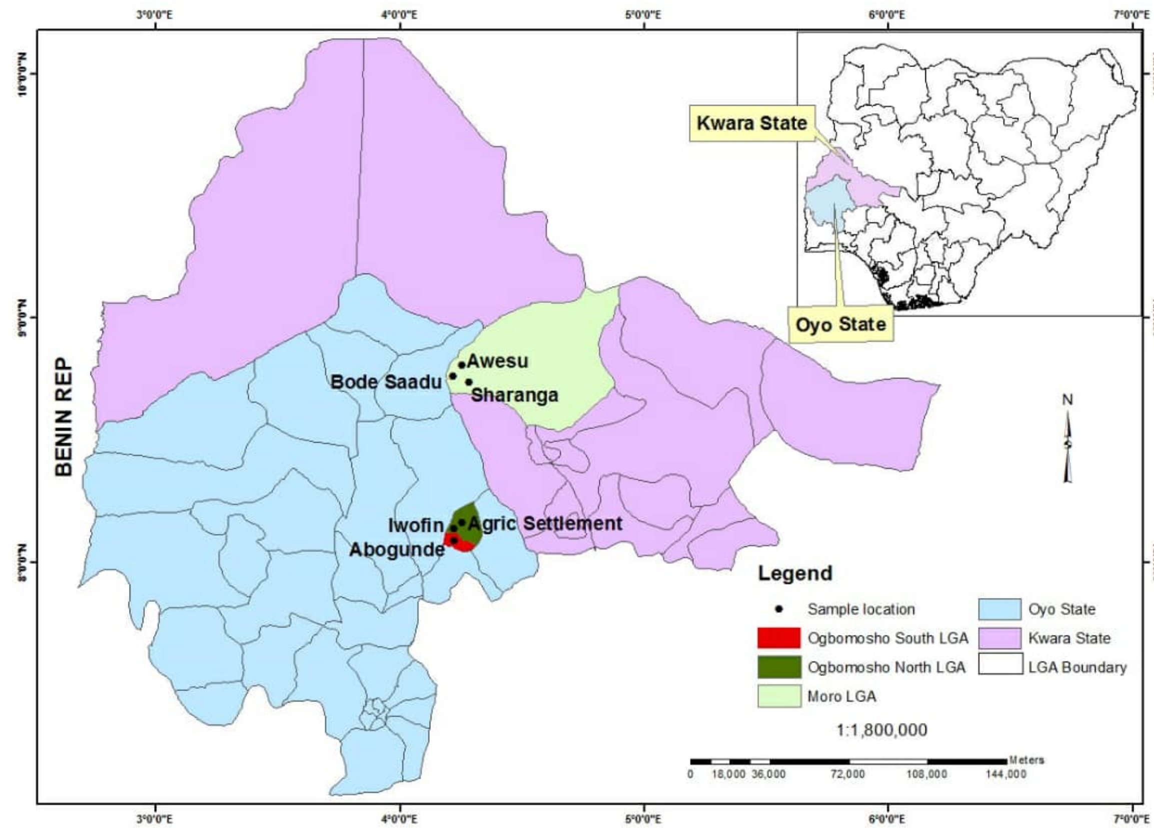

Figure 3.1: Topographical map of study locations- Morro and Ogbomoso Local Government Areas (North and South belonging to one Agriculture extension zone) of Kwara and Oyo States respectively.

3.2. Study two: Chemical composition, and pellet quality and acceptability of urea treated groundnut haulm-based pelleted diets

3.2.1 Experiment one: Chemical composition of groundnut haulms from different locations

3.2.1.1 Proximate composition

The groundnut haulms (Appendix 2) used were collected from Bode Saadu, Ogbomoso, and Akinyele Kraal market, Ibadan. The proximate composition of the haulms was determined according to the methods of AOAC (2002). The parameters analysed for were: dry matter (DM), crude protein (CP), crude fibre (CF), ash, ether extract (EE), and nitrogen-free extract (NFE) was calculated. NFE = 100 % - (% CP + % CF+ % EE +% Ash).

3.2.1.2 Fibre fraction determination: NDF, ADF, ADL of the diets were analysed using the methods of Van Soest *et al.* (1991). Hemicellulose and cellulose were calculated using the equation of Van Soest *et al.* (1991).

3.2.1.3 The mineral composition

The concentration of mineral contents was determined by atomic absorption spectrophotometer after wet digestion in nitric acids and perchloric acid by the method of Fritz and Schenk (1979).

3.2.1.4 Data analysis

All variables were statistically analysed using the general linear model of SAS (2003). Differences among treatment means were tested using DMRT and significance was declared when $P < 0.05$.

3.2.2 Experiment two: Ammoniation and determination of the proximate composition of urea treated groundnut haulms ensiled at different days

3.2.2.1 Experimental site: The ammoniation and ensiling were done at Royal Feedmills, Apata in Ibadan.

3.2.2.2 Procedure for urea treatment (ammoniation) of groundnut haulm

The groundnut haulm was sun-dried and harmer milled. A 4 kg of urea dissolved in 100 L water was carefully sprinkled on 100 kg dry matter (DM) of groundnut haulm spread on large tarpaulin and thoroughly mixed together. The treated groundnut haulm was filled into drums, compacted (Appendix 4), sealed tightly with polyethylene sheets, and then covered with a heavy object placed on the cover to ensure air-tight condition for ensiling. Samples were taken at intervals of 21, 28 and 35 days and analysed for chemical composition and *in vitro* digestibility study.

Experiment three: Proximate composition of urea treated groundnut haulms

The proximate composition of the urea-treated groundnut haulms was determined according to the methods of AOAC (2002).

3.2.3 Chemical composition of dietary feeds

Samples of urea treated (ammoniated) groundnut haulms ensiled for 21 days were selected for diet formulation because they had the highest percentage of crude protein. The urea-treated and untreated groundnut haulm were mixed with other feed ingredients (supplements) to formulate four total mixed diets as presented in Table 3.1. The layout of the diets was as follows:

Diet 1 – Untreated groundnut haulm + supplement (unpelleted, control)

Diet 2 – Urea-Treated groundnut haulm + supplement (unpelleted)

Diet 3 – Untreated groundnut haulm + supplement (pelleted)

Diet 4 – Urea-Treated groundnut haulm + supplement (pelleted)

3.2.3.1 Experimental diets

The urea-treated groundnut haulm was mixed with other feed ingredients to formulate four diets as presented in Table 3.1.

Table 3.1: Ingredients composition (%) of experimental diets

	Diets			
Ingredient (%)	D1	D2	D3	D4
Urea Treated G/ H	-	40.00	-	40.00
Untreated G/H	40.00	-	40.00	-
Brewers Dried Grain	10.50	10.50	10.50	10.50
Dried Cassava Peel	26.00	26.00	26.00	26.00
Wheat bran	9.20	9.20	9.20	9.20
Palm Kernel Cake	10.00	10.00	10.00	10.00
Bone	1.00	1.00	1.00	1.00
Limestone	2.50	2.50	2.50	2.50
Premix	0.55	0.55	0.55	0.55
Salt	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Calculated nutrient composition				
CP (%)	11.26	11.26	11.26	11.26
ME (MJ/Kg DM)	2.17	2.17	2.17	2.17

DI= Untreated unpelleted diet, D2= Urea treated unpelleted diet, D3= Untreated pelleted diet, D4= Urea treated pelleted diet, G/H = Groundnut Haulm, CP = Crude protein, Metabolizable energy was determined using the equation according to Alderman (1985): ME = 11.78 + 0.00654 CP + (0.000665 EE) 2 - CF (0.00414 EE) - 0.0118 Ash.

3.2.3.2 Proximate composition of urea treated and pelleted groundnut haulm based-diets was determined according to the methods of AOAC (2002).

3.2.3.3 Fibre fraction determination

NDF, ADF, and ADLof the diets were analysed using the methods of Van Soest *et al.* (1991). Hemicellulose and cellulose were calculated using the equation of Van Soest *et al.* (1991).

3.2.3.4 Analysis of the mineral composition of experimental diets

The concentration of mineral contents of the experimental diets was determined by atomic absorption spectrophotometer after wet digestion in nitric acids and perchloric acid by the method of Menkel *et al*. (1979).

3.2.3.5 Data analysis

All variables were statistically analysed using the general linear model of SAS (2003). Differences among treatment means were tested using DMRT and significance was declared when $P < 0.05$.

3.2.4 Experiment four: Pellet quality of urea treated and untreated groundnut haulm based diets

3.2.4.1 Experimental location.

Ammoniation and ensiling of groundnut haulm was carried out at a commercial feed mill in Ibadan

3.2.4.2 Pelleting of diets procedure

Pelleting was done at Caps feed, a standard commercial feed mill in Ibadan, Nigeria. Urea treated groundnut haulm was crushed properly with hammer mill and thoroughly mixed with other feed supplements in the ratio 40: 60. The feed mixture waspulverised to ensure fine particle size in order to obtain quality pellet formation. The pulverised feed mixture was transferred into a powered steam boiler pelletiser with an 8mm die installed. The pellets were collected from the outlet, bagged, and carried to a small ruminant pen, Department of Animal Science, University of Ibadan, for the feeding trial. Pellet quality evaluation was done at the faculty of Pharmacy.

3.2.4.3 Pellet hardness determination

3.2.4.4 Experimental site

The study was done at Pharmaceutics and Industrial Pharmacy Laboratory, the University of Ibadan using tablet hardness tester model EH 01 (Appendix 8)

3.2.4.5 Pellet hardness assessment procedure

Twenty samples of pellets with similar lengths from both treated and untreated pellets were subjected to a hardness test using Tablet Hardness Tester. Each pellet was placed in the jaw of the tester and screwed until a break is observed. Once there is a break in the pellet, the reading on the tester remains constant (i.e. no increase or decrease). The constant reading was therefore taken as the hardness of the pellet.

3.2.4.6. Pellet durability index

3.2.4.7 Experimental site:

The analysis was done at Pharmaceutics and Industrial Pharmacy Laboratory, University of Ibadan using the DBK friability test apparatus model (Appendix 9)

3.2.4.8 Pellet durability index assessment procedure

Ten pieces of each sample (i.e. treated and untreated pellets) were measured and introduced into Friability Test Apparatus and allowed to spin for 100 revolutions. At the end of the spinning, the samples were sieved and unbroken pellets weighed, and friability (%) was estimated to determine the durability or ability of the pellet to withstand handling and delivery stress.

Calculation:

$$\textbf{Pellet Durability Index (\%)} = \frac{\text{Initial weight-Final weight (after the crumbs removal)}}{\text{Initial weight}} \times 100$$

3.2.4.9 Data analysis

All variables were statistically analysed using the general linear model of SAS (2003). Differences among treatment means separated by t-test and significance was declared when $P < 0.05$.

3.2.5 Experiment five- Acceptability of urea treated and pelleted groundnut haulm-based diets by West African Dwarf rams

3.2.5.1 Experimental site. The experiments were conducted at the annex of the small ruminant pen of the Teaching and Research Farm of the University of Ibadan, Nigeria. The location falls within 7º 20′ N, 3º 50′ E at an altitude of 200 – 300 m above sea level. It falls within the sub-humid tropics. The annual rainfall ranged from 1150 – 1500 mm. The trial lasted from April to September 2018.

3.2.5.2 Experimental diets

Urea treated and untreated groundnut haulm were separately mixed with concentrate feed ingredients. Two out of the four dietary treatments were pelleted while the remaining two were not pelleted.

The diet layout was as follows:

Diet 1 – Untreated groundnut haulm + supplement mixture (not pelleted, control)

Diet 2 – Urea-Treated groundnut haulm + supplement mixture (not pelleted)

Diet 3 – Untreated groundnut haulm + supplement mixture (pelleted)

Diet 4 – Urea-Treated groundnut haulm + supplement mixture (pelleted)

The gross composition of experimental diets is as shown in Table 1

3.2.5.3 Experimental Animals and management. A total of sixteen West African Dwarf rams, purchased from Iwo, Osun State, and weighing 9.75±1.22kg on average were used for the study. Upon arrival at the experimental site, they were confined in groups for one month for adaptation to stabilize them. Broad-spectrum antibiotic (Oxyteacycline LA) was intramuscularly administered at 1 mL/10 kg body weight and Ivomec super (Ivermectin) at 1 mL/10 kg body weight through a subcutaneous route to control both the endo and ectoparasites.

3.2.5.4 Experimental procedure

A total of sixteen WAD rams were housed in a well-ventilated concrete-floor pen. The floor was covered with wood shaving to serve as absorbent and for easy cleaning of the house. Four feed samples were offered to the animals, 4kg each of the four feed samples were presented on a cafeteria basis to the rams in four separate wooden feeding troughs,and each of the animals had free access to each of the diets in the trough for 5 hours. The positioning of the feeding trough was changed daily to avoid conditioning and learning effects by the animals sticking to the same feed in a particular position. The experiment lasted for ten days. Average daily intake was obtained by deducting the leftover feed from the offered. The coefficient of preference (CoP) was calculated as the ratio of individual intake of the feed and the average intake. Feed samples with CoP less than unity were considered poorly accepted, while CoP greater than unity was better accepted.

CoP = Intake of individual diet Mean intake of the four diet types

3.3. Study three: *In vitro* gas production technique and rumen fermentation characteristics of urea treated groundnut haulm-based pelleted diets

Experimental site

The experiments were conducted at the Department of Animal Science, University of Ibadan

3.3.1 Experiment one: *In vitro* gas production technique of urea treated groundnut haulm; and urea treated and pelleted groundnut haulm based-pelleted diets

Gas production apparatus

The apparatusconsists of long syringes, CO_2 cylinder and regulator, analytical balance and cheesecloth.

3.3.1.1 Preparation and weighing of the feed samples

Samples of each of the treatments diets and urea-treated and untreated groundnut haulms were oven-dried at 105ºC until the constant temperature was obtained. The dry samples were milled with mortar and sieved through 1 mm and 200 mg each of the dry samples was weighed carefully using a digital scale into the fibre bags, and introduced into the cylinder of the long plastic syringe calibrated into 100 mL. The syringes were labelled. Samples were replicated 3 times and an additional blank syringe without substrate. The pistons were greased with Vaseline to ease movement and then pushed down the cylinder gently. The fermentation process took place in the plastic syringe.

3.3.1.2 Preparation of the Buffer Solution

The buffer solution prepared was the McDougall's buffer (pH = 6.8) which consisted of sodium bicarbonate ($NaHCO_3$) sodium Phosphate dibasic ($NaHPO_4$) potassium chloride (KCI), sodium chloride (NaCI), magnesium sulphate ($MgSO_4.7H_2O$) and cacium chloride ($CaCl_2.2H_2O$). The buffer solution was freshly prepared and stored in a dark bottle.

The following were the quantity of reagents used in preparing the buffer.

McDougall's Buffer

	Compound	gm/litre
Sodium bicarbonate	($NaHCO_3$)	9.8
Sodium phosphate diabasic	(Na_2HPO_4)	2.77
Potassium chloride	(KCI)	0.57
Sodium chloride	(NaCI)	0.47
Magnesium sulphate	($MgSO_4.7H_20$)	0.12
Calcium chloride	($CaCl_2.7H_20$)	0.16
Urea	$(NH_2)_2CO$	1.00

3.3.1.3 Collection and preparation of rumen fluid

Rumen liquor was collected from West African Dwarf (WAD) rams fed 60% concentrate and 40% roughage using a suction tube before morning feeding into a prepared flask container pre-heated at 40 ℃. The liquor was sieved with a four-layered cheesecloth and flushed with CO_2 ,and stirring continuously.

3.3.1.4 Preparation of the Rumen Liquor-Buffer Solution

The ruminal liquor-buffer solution were thoroughly mixed in the ratio of 1:4 (v/v) for the incubation.

3.3.1.5 Preparation of the Syringe for Incubation

The syringes with the substrates were arranged into the incubator maintained at 38-39℃ about one hour before the commencement of incubation, and were later inoculated with 30 mL of the rumen fluid buffer, the mixture was introduced into each of the pre-warmed syringes. The ruminal liquor-buffer mixture was the inoculum. The blanksyringes contained only 30 mL of the rumen-buffer solution.

3.3.1.6 Duration of incubation

The experiment lasted for 24 hours and gas released was taken at 3-hours intervals. Gas production was recorded at 3, 6, 9, 12, 15, 18, 21 and 24 hours. The reading of the blank was subtracted from that of the other syringes to obtain the gas produced.

3.3.1.7 Methane (CH_4) determination

A solution of 10 M NaOHwasintroduced into the syringe at the end of the experiment. A4 mL of 10M NaOH was introduced through the silicon tube (4.5cm) fitted to the tips of the syringe to absorb CO_2 leavingthe methane. The syringes were properly shaking to ensure maximum mixing of NaOH solution with the mixture to enable all the CO_2 to be absorbed. The methane produced (left) in the syringe was then recorded in mL.

The gas produced in mL was plotted against the incubation time t. From the graph, the fermentation characteristics were estimated using the equation:

$Y = a + b\,(1- e^{-ct})$ (Ørskov and McDonald, 1979)

Where Y= volume of gas produced at time t (mL)

a = gas produced from the soluble fractions (mL)

b = gas produced from the insoluble but degradable fraction (mL)

t = incubation time (hrs)

c = rate of gas production

(a + b) = potential gas production

Metabolisable energy (ME), organic matter digestibility (OMD), and short-chain fatty acids (SCFA) were estimated as proposed by Menke *et al*. (1979)

ME (MJ/kg DM) = 2.20+0.136GP+0.057CP+0.0029CF

OMD (%) = 14.88+0.889 GP+0.45CP+0.0651XA

SCFA = 0.0239 GP – 0.0601 ((Getachew *et al.*, 1998)

Where:

ME = metabolisable energy;

CP = crude protein in %

CF = crude fibre in %

XA = ash in % and

GP = the net gas production in mL from 200 mg dried sample after 24 hours of incubation. The SCFA was also calculated.

SCFA = Short-chain fatty acids

ME (MJ/Kg DM) = 2.20 + 0.136GP + 0.057CP + 0.002496 CF

OMD (%) = 14.88+ 0.889 GP + 0.45 CP + 0.0651XA

GV: Gas volume (mL)

3.3.1.8 Dry matter degradability

At post-incubation, the rumen liquor was expunged out of the syringes by pushing up the piston. Thereafter, clean water was introduced into the syringes to rinse the fibre/sample bags (containing the degraded substrate) placed inside. The bags were dried to a constant weight at 100°C for 72 hours. The dried weight was recorded and percentage degradation was calculated.

$$\% \text{ dry matter degradability} = \frac{\text{Original weight - final dried weight}}{\text{Original weight}} \times 100$$

3.3.1.9 Data analysis

Data were analysed using the General Linear Model of ANOVA (SAS, 2003). Means were separated using Duncan's Multiple Range Test option of the same software. Significance was declared when $P < 0.05$

3.3.2 Experiment two: Microbial population and ruminal fermentation characteristics in WAD rams fed urea treated and pelleted groundnut haulm based-diets

The experiment was carried out at the Animal Science Department laboratory, University of Ibadan. Ruminal fluid was collected from the experimental animals in each of the four treatment groups before morning feeding with the use of a stomach tube. The suction tube was gently pushed down into the rumen of the animal and sucked with the mouth to ensure the flow of the fluid, about 25 mL of the fluid was collected from each of the representative animals into flask containers and later bulked. The ruminal fluids serves as the source of microbes to the substrates used in the subsequent *in vitro* studies.

3.3.2.1 pH Determination

The pH was measured using a digital pH meter.

3.3.3 Evaluation of microbial (bacteria, fungi and protozoan) population

A total of eight animals consisting of two animals each from the four treatment groups were selected from the animals used for the growth study for the microbial population study. A ruminal fluid sample (100 mL) was taken using a stomach suction tube, before feeding in the morning. Determination of bacteria and fungi population was done using the standard method of pour plate, serial dilution technique, and their relevant growth media. 1mL each of the samples was taken from each replicate, sufficiently serially diluted and streaked onto sterile agar plates, and incubated at 25°C for two days and viable bacteria and fungi were cells counted.

3.3.4 Calculation of microbial population

The estimated number of colonies in the original samples were calculated using the formula:

Colony forming unit (CFU/mL) = Colony count x dilution factor

Protozoa counts were determined by the method of Dehority (1984).

The reagents were Phosphate buffer, 10% formalin, and Glycerol-Buffer-Methyl green mixture. A suction strainer device was used to sample ruminal fluid in a 100 mL tube A 5 mL ruminal fluid was added to a 5 mL formalin solution and mixed. Then 2 mL aliquot of formalinised sample was pipetted into a tube containing an 18 mL glycerol buffer methyl green mixture (1:20 dilution) and mix well. The counting chamber (Sedgewick –Rafter cell) was filled with sample and protozoa and covered then allowed to settle for 10 mins. The eyepiece was used to count the number of organisms using 10 x objective.

Constants:

Eye piece standard square units (one field) = 0.469225 mm^2

Depth of Sedewick-Rafter cell: = 1.00mm

Standard volumetric units = 0.469225 mm^2

Volume of 30 fields =1 x 30 x 0.469225 mm^3

Organism per count = 1000 mm^3/1 x 30m x 0.469225 mm^3

No of protozoa in the fields x dilution x organism per count = Organism/mL

The protozoan count was determined by the procedure of Dehority (1984).

3.3.5 Distillation process and NH_3-N determination

The ruminal fluid sample was filtered through four layers of cheesecloth for ammonia nitrogen (NH_3-N) concentration determination (Beecher and Whitten, 1970). Sample of aliquot (2 mL) of the strained rumen liquor was pipetted into a clean Markham distillation apparatus via its funnel aperture and distilled into a 100 mL conical flask. The distillation is terminated when the distillate volume reached 30 mL in the flask. The distillation was carried out four times for each sample and nitrogen gas bubbled through each distillate to remove dissolved CO_2.

The distillates were titrated against 0.01HCl using the boric acid blue indicator.

%NH_3-N was calculated using the formula:

Titre value x 0.00014 x vol of liquor x 100/ 2 mL of liquor.

3.3.6 Analysis of total volatile fatty acid in rumen liquor distillation method

Total volatile fatty acid (TVFA) was determined by steam distillation (AOAC, 2002). TVFA was calculated using the formula, VFA (mmole/100ml) =Titre value x Molarity of NaOH used x 100 or Meq/100mL

3.3.6.1 Determination of volatile fatty acids fractions (acetic, propionic, and butyric acids) as describedby Montogomery *et al.* (1993).

The individual fractions of acetate, propionate, and butyrate were determined using titration and spectrometric techniques.

Preparation of sample: The rumen liquor was strained through a muslin cloth into a 250 mL beaker. 25 mL of IM H_2SO_4 saturated with $MgSO_4$ was added to the Filtrate in the 250 mL beaker and mixed thoroughly and after 10 mins filtered through a Whatman No 12 filter paper into a 100 mL volumetric flask

Extraction of fatty acids

A 5 mL of the above extract was pipetted into a 250 mL separating funnel and 50 mL of benzene was added to separate the fatty acids. The lower layer was discarded and fatty acid extract, which was the upper layer, was emptied into a 100 ml volumetric flask and makeup with Benzene.

3.3.6.2 Evaluation of propionic acid by spectrophotometer

An aliquot (2ml) of the above extract was introduced into a 30 ml test tube and 10 mL of 10% copper sulphate solution was added to the aliquot and allowed to stand for 20 min to develop a bluish colour solution. Then, 0-10 µg/mL of propionic acid standards were prepared from stock solution (100 µg/ mL propionic acid solution) and treated with 10% copper sulphate.

The absorbance or optical density of sample extract, propionic acid, working standards were read at a wavelength of 515 nm on a Spectronic 2ID spectrophotometer.

The amount of propionic Acid in meq/100mL or mmol/100mL was calculated using the formula.

The absorbance of sample x Gradient factor x Dilution factor.

3.3.6.3 Acetic acid determination by spectrophotometer

A 2 mL of the above extract was introduced into 30 mL test tube and 10 mL of 5% manganese sulphate was added and allowed to stand to develop a Brownish colouration for 5 min. Approximately 0-10 µg/ mL of acetic acid working standards were prepared from 100 µg/mL stock acetic acid solution and treated with 5% manganese sulphate like the sample above.

The absorbances of sample extract as well as acetic acid working standards were read at a wavelength of 585 nm on a Spectronic 2ID spectrophotometer.

Amount of acetic acid in mmol/100mL or meq/100mL = Absorbance of sample x Gradient Factor x Dilution factor.

3.3.6.4 Determination of butyric acid by spectrophotometer

A 2 mL aliquot of the extract was introduced into a 30 mL test tube and 5 mL of stannous chloride solution (20%) was added and allowed to develop a yellowish colour upon standing for 10 min and 0-10 µg/mL of Butyric acid working standards were prepared from a 100 µg/mL stock butyric acid solution and treated with stannous chloride solution.

The absorbance of sample extract and Butyric acid working standards were read at a wavelength of 570 nm on a Spectronic 2ID Spectrophotometer.

The amount of butyric acid in meq/100mL or mmol/100mL was calculated using the formula:

The absorbance of sample x Gradient Factor x Dilution factor

3.3.6.5 Determination of valeric acid by spectrophotometer

A2 mL aliquot of the benzene extract was pipetted into a 30 mL test tube and 10 mL of 5% sodium hydrogen sulphate was added and allowed to develop a brownish colouration for 5 min and 0-10 µg/mL of valeric acid working standards were prepared from a 100 µg/mL stock valeric acid solution and treated with sodium hydrogen sulphate like the sample above.

Amount of valeric acid in mmol/100 mL = Absorbance of sample x Gradient factor x Dilution factor.

3.3.7 Data analysis

All variables were statistically analysed using the general linear model of SAS (2003). Differences among treatment means were tested using DMRT and significance was declared when P< 0.05.

3.4 Study four: Growth Performance, digestibility and nitrogen balance of WAD rams fed urea treated groundnut haulm-based pelleted diets

3.4.1 Experiment one - Growth performance and cost-benefit of WAD rams fed urea treated and pelleted groundnut haulm based diets

3.4.1.1 Experimental site

The feeding trial was carried out at the annex of the small ruminant of Teaching and research farm of the University of Ibadan, Nigeria. The location falls within 7º 20′ N, 3º 50′ E at an altitude of 200 – 300 m above sea level. It falls within the sub-humid tropics. The annual rainfall ranged from 1150 – 1500 mm. The trial lasted from April to September 2018.

3.4.1.2 Experimental diets

Urea treated and untreated groundnut haulm were separately mixed with other feed ingredients. Two out of the four dietary treatments were pelleted while the remaining two were not pelleted.

The diets layout are as follows:

Diet 1 – Untreated groundnut haulm + supplement mixture (not pelleted, control)

Diet 2 – Urea-Treated groundnut haulm + supplement mixture (not pelleted)

Diet 3 – Untreated groundnut haulm + supplement mixture (pelleted)

Diet 4 – Urea-Treated groundnut haulm + supplement mixture (pelleted)

The gross composition of experimental diets was as shown in Table 3.1

3.4.1.3 Experimental animals and management. A total of sixteen West African Dwarf rams purchased from Iwo, Osun State weighing 9.75±1.22 kgon average were used for the study. Upon arrival at the experimental site, they were confined in groups for one month for adaptation to stabilise them.Broad-spectrum antibiotic (Oxyteacycline LA) was administered at 1 mL/10 kg body weight and Ivomec super (Ivermectin) at 1 mL/10 kg body weight through sub-cutaneous route to control both the endo and ecto endoparasites. They were labeled with red painter ink for easy identification. Thereafter, the animals were balanced for weight and moved to individual previously disinfected pens (1m x 1m) with concrete floor and covered with wood shavings. The pens were maintained in a cleaned manner and disinfected to remove faecal droppings, specks of dirt, and odours. Individual wooden feeders and plastic drinking bowls were used to serve the animal's feed and water respectively.

3.4.1.4 Animal feeding

The rams were randomly allotted to four dietary treatments with four replicates (four animals per treatment) in a 2 x 2 factorial arrangement (urea treatment and pelleting as two factors) of a completely randomised design. The control diet included groundnut haulm not treated with urea and also fed in unpelleted form. Animals were fed their assigned total mixed ration once a day at approximately 5% body weight with allowance for refusal and clean-fresh water given *ad libitum*.Rams were weighed before morning feeding to reduce possible gut fill error at the start of the experiment and subsequently once every week until termination of the experiment at 105 days. The difference between the total feed offered and refusals gave the total feed intake. Salt lick was constantly made available for the animals. The parameters considered were: initial body weight, final weight, weight gain, average gain, and feed efficiency.

3.4.1.4 The Cost-benefit analysis

The cost benefit analysis is very vital because it serve as an indicator of the profitability of the exercise.The cost (₦) per kg of the diet was calculated by multiplying the percentage composition of the ingredient with the price per kg of each ingredient and adding it all together. The total feed cost (₦) was obtained from total feed intake multiply by the cost (₦) per kg feed. The monetary value of weight gain (₦) was calculated by multiplying weight gain by cost (₦) per kg mutton. The net benefit (₦), which is a measure of profitability was obtained from the difference between the monetary value of weight gain (₦) and total feed cost (₦).

3.4.2 Experiment three - Nutrient digestibility, nitrogen utilisation, and microbial protein synthesis

The experimental animals were allotted to the four treatment diets. Animals were housed individually in metabolic cages which allows for separate urine and faecal collection. A seven-day adjustment period was observed before the subsequent seven days when feed was offered and refused as well as faeces and urine were collected for laboratory analysis. The animals were fed were fed at 5% of their body weight. Nitrogen loss from the urine due to volatisation through microbial activities was prevented by adding 10 mL of 10% H_2SO_4 into the container for collecting the urine sample. Daily collections of faeces and urine were separately bulked and a 10% subsample (aliquot) of each was taken for analysis. Faecal samples were oven-dried at 105℃ for 24 hours. The urine samples were stored in an airtight container and kept in a refrigerator at 4℃ until required for analysis.

Microbial protein synthesis (MPS) was estimated as described by Chen and Gomes (1995) equation.

Microbial nitrogen (MN) yield = 32 g/kg x OMDR

OMDR = Organic matter digested in the rumen,

Where OMDR = Feed intake × DM content × OM content × OM digestibility × 0.65

DM= Dry Matter and OM = Organic Matter

3.4.3 Chemical analysis

The Proximate compositions were determined according to the methods of AOAC (2002) fibre fractions, hemicellulose, and cellulose were determined according to the procedure of Van Soest *et al.* (1991).

3.4.4 Data analysis

3.4.5 Experimental model:

$Yijk = \mu + Ai + Bj + (AB)\ ij + \varepsilon ijk\ i = 1, a; j = 1,\ldots,b; k = 1,\ldots,n$

All variables were statistically analysed using the general linear model of ANOVA (SAS, 2003)and significance was declared when $P < 0.05$.

Table 4.1: Socio-economic characteristics of groundnut farmers in

CHAPTER FOUR
RESULTS

4.1 Study one: Groundnut production and haulm utilisation in Morro LGA and Ogbomoso (north and south) LGA of Kwara and Oyo States respectively

4.1.1 Socio-economic characteristics of groundnut farmers

The socio-economic characteristics of the groundnut farmers are presented in Table 4.1. From the analysis, the majority of the respondents were male (91.7%), comprising 96.7% from Morro and 86.7% from Ogbomoso. A large portion of the farmers (90.0%) fell within 21-60 years with more farmers (53.3%) falling within 41-60 years from Morro and 57.0% falling within 20-40 years for the respondents from Ogbomoso. All the respondents (100%) from Ogbomoso were married while 93.3% of them from Morro were married. The majority (40%) of respondents from Morro had 6-10 household size compared to Ogbomoso where the household size range of 1-5 was the highest (50%). Most of the farmers from Morro (53.3%) were educated in Arabic whereas 53.3% of the respondents from Ogbomoso had secondary school education. Those with primary school education in both locations were 33.3% and 23.3% for Ogbomoso and Morro respectively. The dominating occupation from the study locations was farming (78. 4%) consisting of 86.7% and 70% for respondents from Morro and Ogbomoso respectively.

The sex and education of the respondents are further represented by charts on pages 51 and 52 respectively.

Morro and Ogbomoso LGA of Kwara and Oyo States respectively

Variables	Groundnut farmers (%) Morro (n=30)	Ogbomoso (n=30)	Average (%)
Sex			
Male	96.70	86.70	91.70
Female	3.30	13.30	8.30
Total	100.00	100.00	100.00
Age			
<20	10.00	0.00	5.00
21-40	26.70	57.00	41.85
41-60	53.30	43.00	48.15
>60	10.00	0.00	5.00
Total	100.00	100.00	100.00
Marital status			
Married	93.30	100.00	96.65
Single	6.70	0.00	3.5
Total	100.00	100.00	100.00
Household size			
1-5	33.30	50.00	41.65
6-10	40.00	30.00	35.00
>10	26.70	20.00	23.35
Total	100.00	100.00	100.00
Educational level			
Primary	23.30	33.30	28.30
Secondary	13.30	53.30	33.30
Tertiary	6.70	13.30	10.00
Arabic	53.30	0.00	26.65
None	3.30	0.00	1.65
Total	100.00	100.00	100.00
Occupation			
Trading	10	23.3	16.65
Civil Service	3.3	0	1.65
Farming	86.7	70	78.35
Artisan	0	6.7	3.35
TOTAL	100	100	100

Source: Field survey, 2017

N = Number of respondents in respective variable groups

4.1.2 Groundnut production in the studied areas

Groundnut production in the study locations is presented in Table 4.2. The majority of the farmers (80%) cultivated about 1-2 ha of groundnut, 90%, and 70% were from Morro and Ogbomoso respectively. Farmers from Morro had a higher yield, as 66% of them recorded more than 2 tonnes per hectare, compared to Ogbomoso where only 22% had more than 2 tonnes per hectare. All the respondents (100%) engaged in groundnut production only during the rainy season. The major source of funds available to them was from friends and family (53.57%) consisting of 57.3% for Morro and 50% for farmers from Ogbomoso. This is followed by personal savings, 46.7% for groundnut farmers in Ogbomoso and 20% for farmers from Morro. The sources of labour were mainly hired and family representing (55.0%) and (45.0%) for each location respectively while communal labour was not available in either of the two locations.

Table 4.2: Groundnut production in Morro and Ogbomoso (LGAs) of Kwara and Oyo States respectively

	Groundnut production (%)		
Parameters	Morro (n= 30)	Ogbomoso (n= 30)	Average (%)
Groundnut farm(Ha)			
1-2 ha	70.00	90.00	80.00
>2 ha	30.00	10.00	20.00
Total	100.00	100.00	100.00
Yield in tonnes per ha			
1-2 tonnes	33.30	80.00	56.65
>2	66.70	20.00	43.35
Total	100.00	100.00	100.00
Season(s) of production			
Rainy	100.00	100.00	100.00
Dry	0.00	0.00	0.00
Both	0.00	0.00	0.00
Total	100.00	100.00	100.00
Sources of fund			
Personal Saving	20.00	46.70	33.35
Friends and family	56.70	50.00	53.35
Banks	0.00	0.00	0.00
Cooperative	3.30	0.00	1.65
Buyer	20.00	3.30	11.65
Total	100.00	100.00	100.00
Sources of labour			
Family	46.70	43.30	45.00
Hired	53.30	56.70	55.00
Communal	0.00	0.00	0.00
Total	100.00	100.00	100.00

Source: Field survey, 2017

4.1.3 The need assessment and suggested solution

Table 4.3 shows the five major problems facing the farmers and suggested solutions from PRA exercise. The problems identified by the farmers were drought, pest/diseases, labour, animal invasion, and inadequate finance. The suggested solutions include the provision of irrigation facilities, chemicals to control diseases, modern farm implements, restriction of open grazing, and accessible funds like a loan for agribusiness.

Table 4.3: The need assessment of groundnut production in Morro and Ogbomoso LGAs

Serial no	Constraint	Solution
1.	Drought	Provision of Irrigation
2.	Pest/Diseases	Rodenticides and disease resistant cultivars
3.	Labour	Farm implement should be provided
4.	Animal invasion	Open grazing should be prohibited
5.	Inadequate finance	Agricultural loan should be made available

4.1.4 The pair-wise comparison of groundnut production

The result of Focus Group Discussion (FGD) among the groundnut farmers in Morro and Ogbomoso using a pair-wise ranking technique of comparing two problems at a time with the farmers deciding which of the problem was more important is presented in Table 4.4. Constraint or problem 5 which was inadequate finance had the highest frequency of five in both Morro and Ogbomoso followed by drought, problem (1) in both locations. Animal invasion (4) was ranked higher in Ogbomoso than pest/diseases (2) but the reverse was the case in Morro as pest/disease (2) had a frequency of (1) and zero for animal invasion

Table 4.4: The pair-wise comparison of groundnut production problems at Ogbomoso and Morro LGAs

	Farmers ranking of the constraints	
	Morro	Ogbomoso
Comparison	More important	More important
Constraint 1 Vs Constraint 2	1	1
Constraint 1 Vs Constraint 3	1	1
Constraint 1 Vs Constraint 4	1	1
Constraint 1 Vs Constraint 5	5	5
Constraint 2 Vs Constraint 3	3	2
Constraint 2 Vs Constraint 4	2	4
Constraint 2 Vs Constraint 5	5	5
Constraint 3 Vs Constraint 4	3	4
Constraint 3 Vs Constraint 5	5	5
Constraint 4 Vs Constraint 5	5	5

Vs= Versus

Constraint 1=Drought, constraint 2 = pest/diseases, constraint 3 = labour,

constraint 4 = animal invasion, constraint 5 = inadequate finance

4.1.5 Farmers' awareness of groundnut haulm as livestock feed and its alternative uses

Indicated in Table 4.5 is the farmers' awareness of groundnut haulm as livestock feed and its alternative uses in Morro and Ogbomoso. All the respondents (100%) from Ogbomoso were not aware that groundnut haulm is a feed resource for livestock. Similarly, 96.7% of farmers from Morro were not aware that it could be fed to livestock as feed. On average, 98.4% of the farmers were ignorant of groundnut haulms as a livestock feed resource. Most farmers (81.7%) left the haulm to decay in the field while some farmers (16.65%) allowed it to be grazed by cattle together with other weeds.

Table 4.5: Farmers' awareness of groundnut haulm as livestock feed and its alternative uses in Morro and Ogbomoso (LGAs) of Kwara and Oyo States respectively

	Farmers Awareness (%)		
Parameters	**Morro (n=30)**	**Ogbomoso (n= 30)**	**Average (%)**
Awareness of groundnut haulm as a livestock feed			
Aware	3.30	0.00	1.65
Not aware	96.70	100.00	98.35
Total	100.00	100.00	100.00
Haulm use after groundnut Harvest			
As livestock Feed	3.30	0.00	1.65
Burnt it	0.00	0.00	0.00
Left to decay	63.40	100.00	81.70
Grazed with other weeds by cattle	33.30	0.00	16.65
Total	100.00	100.00	100.00

Source: Field survey, 2017

4.2 Study two: Chemical composition, pellet quality, and acceptability of urea treated groundnut haulm-based pelleted diets

4.2.1 Chemical composition of groundnut haulms from different locations

The chemical composition of groundnut haulms from different locations is presented in Table 4.6. Dry matter of groundnut haulm from Bode Saadu (93.08±0.04%) and Ogbomoso (93.03±0.09%) were similar but higher ($P < 0.05$) different from Akinyele (92.91±0.06%). Crude protein of 13.21±0.18% (Bode Saadu) was significantly ($P < 0.05$) higher than 8.20±0.05% (Ogbomoso) and 8.35±0.02% (Akinyele). Ash content of 15.90±0.03% (Bode Saadu) and 15.92±0.08% (Ogbomoso) were similar but higher ($P < 0.05$) than from 2.63±0.03% (Akinyele). Ether extract from the three locations was similar 17.15±0.132% (Bode Saadu), 2.60±0.01% (Ogbomoso) and 2.52±0.18%(Akinyele). Crude fibre of 30.52±0.03% (Akinyele) was higher ($P < 0.05$) than 25.05±0.05% (Ogbomoso) and 25.04±0.03% (Bode Saadu). Nitrogen-free extract of 48.23±0.20% from Ogbomoso was higher than 43.22±0.06% and 41.46±0.06% from Bode Saadu and Akinyele respectively. Neutral detergent fibre of 45.99±0.07% (Bode Saadu) and 46.01±0.09% (Ogbomoso) was similar and higher ($P < 0.05$) than 60.13±0.13% (Akinyele). The acid detergent fibre was higher (50.01±0.14%) in groundnut haulm from Akinyele than 40.00±0.04% and 39.99±0.01% for Bode Saadu and Ogbomoso respectively. Acid detergent lignin of 18.52±0.05% (Bode Saadu) and 18.50±0.05% (Ogbomoso) were similar but lower ($P < 0.05$) than 25.22±4.14% (Akinyele). The cellulose of 24.79±4.26% (Akinyele) was higher ($P<0.05$) than 21.51±0.09% and 21.49±0.04% from Bode Saadu and Ogbomoso respectively. Hemicellulose of 10.13±0.22% (Akinyele) was higher ($P < 0.05$) than 6.02±0.076% (Ogbomoso) and 5.98±0.11% (Bode Saadu).

Table 4.6: The chemical composition (% DM) of groundnut haulms from different locations

Parameters	Locations		
	BDS	OGB	AKY
DM	93.08±0.04[a]	93.03±0.09[a]	92.91±0.06[b]
CP	13.21±0.18[a]	8.20±0.05[b]	8.35±0.02[b]
ASH	15.90±0.03[b]	15.92±0.08[b]	17.15±0.13[a]
EE	2.63±0.03	2.60±0.01	2.52±0.18
CF	25.04±0.04[b]	25.05±0.05[b]	30.52±0.03[a]
NFE	43.22±0.06[b]	48.23±0.10[a]	41.46±0.20[c]
NDF	45.99±0.07[c]	46.01±0.09[c]	60.13±0.13[a]
ADF	40.00±0.04[b]	39.99±0.01[b]	50.01±0.14[a]
ADL	18.52±0.05[b]	18.50±0.05[b]	25.22±4.14[a]
CELLULOSE	21.51±0.09[b]	21.49±0.04[b]	24.79±4.26[a]
HEMICELLULOSE	5.98±0.11[b]	6.02±0.076[b]	10.13±0.22[a]

[a,b,c] means within the same row with different superscripts are significantly different ($p<0.05$). CP = crude protein, CF = crude fibre, DM = dry matter, EE = ether extract, NFE = nitrogen free extract, NDF= neutral detergent fibre, ADF= acid detergent fibre, ADL= acid detergent lignin, HEMICELL= hemicellulose, OGB=Ogbomoso, BDS= Bode Saadu, AKY= Akinyele Kraal market

4.2.2 Mineral composition of groundnut haulms from different locations

The mineral composition of groundnut haulms from different locations is represented in Table 4.7. Calcium (Ca) from Bode Saadu (0.25±0.01%) was higher ($P<0.05$) than 0.21±0.01% and 0.20±0.01% from Ogbomoso and Akinyele respectively. Phosphorus (P) of 0.34±0.02% (Bode Saadu) and 0.32±0.02% (Akinyele) were similar but higher ($P<0.05$) than from 0.28±0.02% (Ogbomoso). Magnesium (Mg) of 0.21±0.01% (Akinyele) and 0.22±0.01% (Ogbomoso) were similar ($P>0.05$) but lower ($P < 0.05$) than 0.26±0.05 % (Bode Saadu). Potassium (K) of 0.73±0.01% (Bode Saadu) was higher ($P <0.05$) than 0.48±0.01% and 0.49±0.02% values for groundnut haulms from Akinyele and Ogbomoso, respectively. Sodium (Na) value of 0.16±0.01% from Bode Saadu was higher ($P<0.05$) than 0.12±0.01% and 0.10±0.01% from Ogbomoso and Akinyele respectively. Zinc (Zn) of 31.16±0.025 mg/Kg from Bode Saadu was higher ($P<0.05$) than 21.67±0.02 mg/Kg and 18.76±0.01 mg/Kg from Akinyele and Ogbomoso respectively. Iron (Fe) for groundnut haulms from Akinyele had the highest value of 131.48±0.24 mg/Kg followed by 118.61±0.04 mg/Kg for Ogbomoso and the lowest value of 34.79±0.04 mg/Kg for Bode Saadu.

Table 4.7: Mineral composition of groundnut haulms from different locations

Location	Minerals						
	Ca (%)	P (%)	Mg (%)	K (%)	Na (%)	Zn (mg/Kg)	Fe (mg/Kg)
BDS	0.25±0.01[a]	0.34±0.02[a]	0.26±0.05[a]	0.73±0.01[a]	0.16±0.01[a]	31.16±0.025[a]	34.79±0.04[c]
OGB	0.21±0.01[b]	0.28±0.02[b]	0.22±0.01[b]	0.49±0.02[b]	0.12±0.01[b]	21.67±0.02[b]	118.61±0.04[b]
AKY	0.20±0.01[c]	0.32±0.02[a]	0.21±0.01[b]	0.48±0.01[b]	0.10±0.01[c]	18.76±0.01[c]	131.48±0.24[a]
SEM	0.02	0.01	0.03	0.20	0.001	2.00	6.58

[a,b,c] Means in the same column with different superscripts are significantly different ($p<0.05$), OGB = Ogbomoso, BDS-=Bode Saadu, AKY= Akinyele Kraal market, Ca= Calcium, P = Phosphoros, Mg= Magnesium, K= Potassium, Na= Sodium, Fe = Iron, Zn = Zinc

4.2.3 The proximate composition of urea-treated groundnut haulm ensiled for different days

The proximate composition of urea-treated groundnut haulm and ensiled for different days are shown in Table 4.8. The dry matter value of 94.07±0.020% for day 21 (D21) was higher ($P<0.05$) than 93.56±0.055% and 93.46±0.078% obtained for the day (D28) and day 35 (D35), respectively. Crude protein of 26.25±0.05% for (D21) was the highest followed by 19.95±0.05% for day 28 (D28) and lowest value of 16.43±0.03% for D35. The ash content ranged from 15.11±0.040% (D28) to 19.36±0.55% (D35). The ether extract of 3.80±0.265% (D21) was higher ($P<0.05$) than 2.50±0.07% for D28 and 2.33±0.03% for D35. The crude fibre of 24.65±0.52% for D35 and 24.09±0.04% for D28 were similar ($P>0.05$) but higher than 21.20±0.20% for D21. The nitrogen-free extract of 38.39±0.02% and 37.22±0.32% for D28 and D35 were similar ($P>0.05$) but higher ($P < 0.05$) than 31.74±0.10% for D21.

Table 4.8: The proximate composition of urea treated groundnut haulm and ensiled for different days

	Parameters (%)					
Duration	DM	CP	ASH	EE	CF	NFE
D21	94.07±0.020[a]	26.25±0.050[a]	17.01±0.012[b]	3.80±0.265[a]	21.20±0.20[b]	31.74±0.10[b]
D28	93.56±0.055[b]	19.95±0.050[b]	15.11±0.040[c]	2.50±0.070[b]	24.09±0.04[a]	38.39±0.02[a]
D35	93.46±0.078[b]	16.43±0.029[c]	19.36±0.55[a]	2.33±0.029[b]	24.65±0.52[a]	37.22±0.32[a]
SEM	0.01	0.54	0.68	1.15	0.24	1.45

[a,b,c] Means in the same column with different superscripts are significantly different ($p<0.05$), CP = crude protein, CF = crude fibre, DM = dry matter, EE = ether extract, NFE = nitrogen free extract, D1 = Twenty one days ensiled, D28= Twenty eight days ensiled, D35= Thirty five days ensiled

4.2.4 Proximate composition (%) of urea treated and untreated groundnut haulm

Table 4.9 reveals the proximate composition of urea-treated groundnut haulm (UTGH) and untreated groundnut haulm (UGH). The dry matter values of 94.07±0.20% and 93.08±0.36% for UTGH and UGH respectively, were similar. The crude protein value of 26.25±0.50% for UTGH was higher ($P<0.05$) than 13.21±0.18%for UGH. The ash content for both treatments was not ($P >0.05$) different. Ether extract for UTGH (3.80±0.26%) was higher ($p < 0.05$) than untreated (2.63±0.31%). The value of 21.20±0.20% for UTGH was lower ($P<0.05$) than 25.04±0.36% for the UGH. Nitrogen free extract of 43.22±1.04% for UGH was higher ($P < 0.05$) than 31.74±0.13% for UTGH.

Table 4.9 : Proximate composition (%) of Urea treated and untreated groundnut haulm

	Treatment			
Parameters	UGH	UTGH	SEM	P-values
Dry matter	93.08±0.36	94.07±0.20	1.20	0.294
Crude protein	13.21±0.18[b]	26.25±0.50[a]	4.28	0.040
Ash	15.90±0.30	17.01±0.01	1.86	0.339
Ether extract	2.63±0.31 [b]	3.80±0.26 [a]	1.32	0.038
Crude fibre	25.04±0.36[a]	21.20±0.20[b]	2.54	0.0001
NFE	43.22±1.04[a]	31.74±0.13[b]	3.24	0.0021

[a,b] Means in the same row with different superscripts are significantly different ($p<0.05$).

UGH= Untreated groundnut haulm, UTGH= Urea- treated groundnut haulm, NFE= Nitrogen Free Extract.

4.2.5 Chemical composition (%) of diets fed to WAD rams

Table 4.10 presents the proximate composition of urea treated groundnut haulm pelleted feedstuff fed to WAD rams. The diets consist of untreated unpelleted (D1), treated unpelleted (D2), untreated pelleted (D3) and treated pelleted (D4). Dry matter ranged from 93.08±0.66% (D3) to 93.64±0.53% (D4) and was similar (P>0.05) across treatment. Organic matter followed the same trend as dry matter and ranged from (79.59±0.53%) D4 to (81.63±0.66%) D3 and was not (P>0.05) different. Crude protein contents of D1 (11.85±0.74%), D2 (11.39±0.97%) and D4 (11.33±0.62%) was similar (P>0.05) but higher (P < 0.05) than D3 (9.54±0.68%). The ash content ranged from 11.45±0.51% (D3) to 12.75±0.43% (D4) and was similar (P>0.05) across the treatments. Ether extract value for D3 (3.03±0.10%) was highest and lowest in D1 (2.22±0.13%) but similar (P>0.05) for D2 (2.40±0.12%) and D4 (2.42±0.11%). Crude fibre values of 25.91±1.16% for D3 and 25.72±1.91% for D4 was similar (P>0.05) but higher (P<0.05) than 23.56±1.13% and 23.59±1.12% for D1 and D2 respectively. Nitrogen free extract of 49.87±0.41% for D4 was lower (P< 0.05) than 49.84±0.21%, 49.87±0.41% and 50.07±0.46% for D1, D2 and D3 respectively.

Table 4.10 : Proximate composition (%) of diets fed to WAD rams

Diets	Parameters						
	DM (%)	OM (%)	CP (%)	ASH (%)	EE (%)	CF (%)	NFE (%)
D1	93.43±0.61	80.90±0.61	11.85±0.74[a]	12.53±0.50	2.22±0.13[c]	23.56±1.13[b]	49.84±0.21[b]
D2	93.59±0.56	80.84±0.56	11.39±0.97[a]	12.75±0.43	2.40±0.12[b]	23.59±1.12[b]	49.87±0.41[b]
D3	93.08±0.66	81.63±0.66	9.54±0.68[b]	11.45±0.51	3.03±0.10[a]	25.91±1.16[a]	50.07±0.46[a]
D4	93.64±0.53	79.59±0.53	11.33±0.62[a]	14.05±1.81	2.42±0.11[b]	25.72±1.91[a]	46.48±0.32[c]
SEM	0.84	0.82	2.42	2.80	0.60	2.01	0.20

[a,b,c] Means in the same column with different superscripts are significantly different ($p<0.05$). DM= Dry Matter, OM =Organic Matter, CP= Crude Protein, EE= Ether Extract, CF= Crude Fibre, D1= Untreated unpelleted , D2= Urea Treated unpelleted, D3= Untreated pelleted , D4= Urea Treated pelleted

4.2.6 Fibre fractions of the diets fed to WAD rams

Presented in Table 4.11 are the fibre fractions of the feedstuff fed to WAD rams.

The NDF values for all the treatments were not different (P>0.05). The acid detergent fibre of 42.58±2.53%, 42.58±2.53%, 41.51±1.38% for D2, D3, and D4, respectively were similar (P>0.05) but higher (P<0.05) than 39.87±0.98% for D1. The acid detergent lignin of D1 (19.30±0.93%), D2 (21.10±1.93%), D3 (20.88±1.07%), and D4 (19.70±1.39%) was the same (P>0.05). Cellulose value of D1 (20.57±0.06%) was lower (P < 0.05) than the values of 21.48±0.64%, 21.40±0.15% and 21.82±0.06% for D2, D3 and D4 respectively. Hemicellulose values ranged from 13.16±2.00% (D4) to 14.60±2.06% (D1) and were similar (P>0.05)across the treatment diets.

Table 4.11: Fibre composition of experimental diets

Treatment	Fibre fractions (%)				
	NDF	ADF	ADL	Cellulose	Hemicellulose
D1	54.47±1.08	39.87±0.98[b]	19.30±0.93	20.57±0.06[b]	14.60±2.06
D2	56.87±1.32	42.58±2.53[a]	21.10±1.93	21.48±0.64[a]	14.29±2.20
D3	56.66±1.09	42.28±0.99[a]	20.88±1.07	21.40±0.15[a]	14.38±2.08
D4	54.67±2.38	41.51±1.38[a]	19.70±1.39	21.82±0.06[a]	13.16±2.00
SEM	1.04	1.35	1.95	0.96	1.54

[a,b] Means in the same column with different superscripts are significantly different ($p<0.05$). NDF= Neutral Detergent Fibre, ADF= Acid Detergent Fibre, ADL= Acid Detergent Lignin, D1= Untreated not pelleted , D2= Urea Treated not pelleted, D3= Untreated pelleted , D4= Urea Treated pelleted

4.2.7 Mineral composition of the diets fed to WAD rams

Table 4.12 reveals the mineral composition of the diets fed to WAD rams. The Ca value of D3 (0.29±0.006%) was higher ($P < 0.05$) than those of other treatments while D2 (0.27±0.001%) and D3 (0.27±0.001%) had similar ($P>0.05$) values but higher ($P<0.05$) than the value of 0.26±0.0005% for D1. Phosphorous ranged from 0.34±0.001% (D1) to 0.36±0.003% (D3) with the values of 0.36±0.001% and 0.36±0.003% for D3 and D4, respectively similar ($P>0.05$) but higher ($P<0.05$) than 0.35±0.001 for D2 but lowest ($P<0.05$) content in D1 (0.34±0.001%). The magnesium for D2 (0.26±0.001%) and (0.26±0.001%) were significantly higher than 0.25±0.00% for D4 which in turn was also higher than 0.23±0.003% for D1. Potassium content of 0.69±0.01% in D4 was highest and lowest in D1 (0.69±0.01%). There were significant differences ($P<0.05$) among all the treatments for sodium in increasing order from 0.14±0.01% (D1), 0.17±0.01% (D2), 0.18±0.001% (D4) and 0.19±0.003% (D3) respectively. Manganese contents significantly ($P<0.05$) increased from 34.62±0.03 mg/kg (D3), 37.30±0.01 mg/kg (D4), 37.50±0.01 mg/kg (D1) to 42.30±0.01 mg/kg (D2). There were significant differences for values for zinc among the treatments, D1 had the highest ($P<0.05$) value of 33.40±0.01 mg/kg while D4 had the lowest value of 25.80±0.01 mg/kg.

Table 4.12 : Mineral composition of groundnut haulm-based pelleted diets

Treatment	Minerals						
	Ca (%)	P (%)	Mg (%)	K (%)	Na (%)	Mn (mg/kg)	Zn (mg/Kg)
D1	0.26±0.0005[c]	0.34±0.0005[c]	0.23±0.003[c]	0.59±0.01[d]	0.14±0.01[d]	37.50±0.01[b]	33.40±0.01[a]
D2	0.27±0.001[b]	0.35±0.001[b]	0.26±0.001[a]	0.64±0.001[b]	0.17±0.01[c]	42.30±0.01[a]	31.60±0.01[b]
D3	0.29±0.006[a]	0.36±0.003[a]	0.26±0.001[a]	0.61±0.009[c]	0.19±0.003[a]	34.62±0.03[c]	28.31±0.03[c]
D4	0.27±0.001[b]	0.36±0.001[a]	0.25±0.00[b]	0.69±0.01[a]	0.18±0.001[b]	37.30±0.01[b]	25.80±0.01[d]
SEM	0.001	0.001	0.001	0.002	0.003	2.010	1.500

[a,b,c,d]Means in the same column with different superscripts are significantly different ($p<0.05$), SEM = standard error of means Ca= Calcium, P = Phosphorus, Mg= Magnesium, K= Potassium, Na= Sodium, Mn = Manganese, Zn = Zinc, D1= Untreated not pelleted , D2= Urea Treated not pelleted, D3= Untreated pelleted , D4= Urea Treated pelleted

4.2.8Pellet quality of urea treated and untreated groundnut haulm based diets.

The pellet hardness and durability of urea treated groundnut haulm diets were shown in Table 4.13. The pellet hardness value of 207.58±51.35 N for the urea treated groundnut haulm diet was significantly ($P < 0.05$) higher than 146.28±48.37 N for the untreated diet. However, the durability value of 99.38±0.42% for urea treated groundnut haulm diets was similar ($P > 0.05$) to 94.16±7.62 % for the untreated.

Table 4.13: Pellet hardness and durability of urea treated and untreated groundnut haulm based diets

Parameter	Treatment		SEM	p-values
	Urea treated pellet	Untreated pellet		
Hardness (N)	207.58[a]	146.28[b]	50.23	0.004
Durability (%)	99.38	94.16	6.23	0.493

[a,b] Means in the same row with different superscripts are significantly different ($p<0.05$)., N = Newton, SEM = standard error of the means

4.2.9 Acceptability of urea treated and pelleted groundnut haulm based-diets by WAD rams

The coefficient of preference (CoP) among the various forms of feeds fed to the animals is presented in Table 4.14. The coefficient of preference ranged from 0.26 in D2 (treated unpelleted) to 2.25 in D1 (untreated unpelleted). The animals preferred the untreated unpelleted diet to others. The increasing order of preference was treated unpelleted (D2), treated pelleted (D4), untreated pelleted (D3), and untreated unpelleted (D1).

Table 4.14: Preferences of the various diets by West African Dwarf Rams.

Diets	Average daily feed untake (kg)	Coefficient of preference
DI	2.30	2.25
D2	0.26	0.26
D3	1.07	1.04
D4	0.46	0.44

DI = Untreated unpelleted, D2= Treated unpelleted, D3= untreated pelleted, D4 = treated pelleted

4.3 study three: *In vitro* gas production and rumen fermentation characteristics of urea treated groundnut haulm feedstuff

4.3.1 *In vitro* fermentation characteristics of urea treated and untreated groundnut haulm for 24 hours

Table 4.15 shows the *in vitro* fermentation characteristics of urea treated and untreated groundnut haulms. There was no or undetectable gas production from the soluble fraction ('a') of the substrate. The gas production value of 10.67±8.08 mL from an insoluble but degradable fraction ('b') for untreated groundnut haulm was significantly ($P < 0.05$) higher than 10.67±8.08 mL for urea treated groundnut haulm. The potential extent of gas production (a+b) followed a similar pattern. The gas production rate constants ('c') observed for untreated (0.06±0.012 $mLh^{-1)}$ and treated groundnut haulm (-0.14±0.04 $mLh^{-1)}$ were similar. The incubation time (t; hrs) for untreated groundnut haulm 19.00±3.46 was higher ($p < 0.05$) than 15.00±0.00 h for the treated groundnut haulm. The gas 'Y'at 't' for untreated groundnut haulm (2.00±0.00mL) was lower ($P<0.05$) than 7.67±5.51 mL for urea treated groundnut haulm.

Figure 4.5 represents the graphical illustration of *invitro* gas production of urea treated and untreated groundnut haulm at a 24 hour incubation period. The graphs reveal that untreated groundnut haulm started gas production earlier after 6 hrs of incubation and in the end, had a higher value of gas production of (10.67 mL) compared to gas production commencement time of 9hrs and total gas volume of (2.00 mL) for urea treated groundnut haulm.

The rate of degradability and undegradability of urea treated and untreated groundnut haulms were shown in Figure 4.6. It was observed from the chat, that degradability for urea treated groundnut haulm (45%) was numerically higher than untreated groundnut haulm (37%).

Table 4.15 : *In vitro* fermentation characteristics of urea treated and untreated groundnut haulm at 24 hour incubation period

Variable	Treatment		SEM	P-values
	UGH	UTGH		
a (mL)	0.00±0.00	0.00±0.00	0.00	0.00
b (mL)	2.00±0.00[b]	10.67±8.08[a]	1.87	0.016
a+b (mL)	2.00±0.00[b]	10.67±8.08[a]	1.87	0.016
c (mLh^{-1})	0.06±0.012	0.14±0.04	0.13	0.074
t (hr)	19.00±3.46[a]	15.00±0.00[b]	0.18	0.016
Y (mL)	2.00±0.00[b]	7.67±5.51[a]	1.20	0.018

[a,b] Means in the same row with different superscripts are significantly different ($p<0.05$), SEM = standard error of the means

UGH- Untreated groundnut haulm

UTGH- Urea treated groundnut haulm

a - The gas production from the soluble fraction

b -The gas production from the insoluble but degradable fraction

a + b - Potential extent of gas production fraction

c - Gas production rate constant

t - Incubation time

Y - Gas volume production at time t

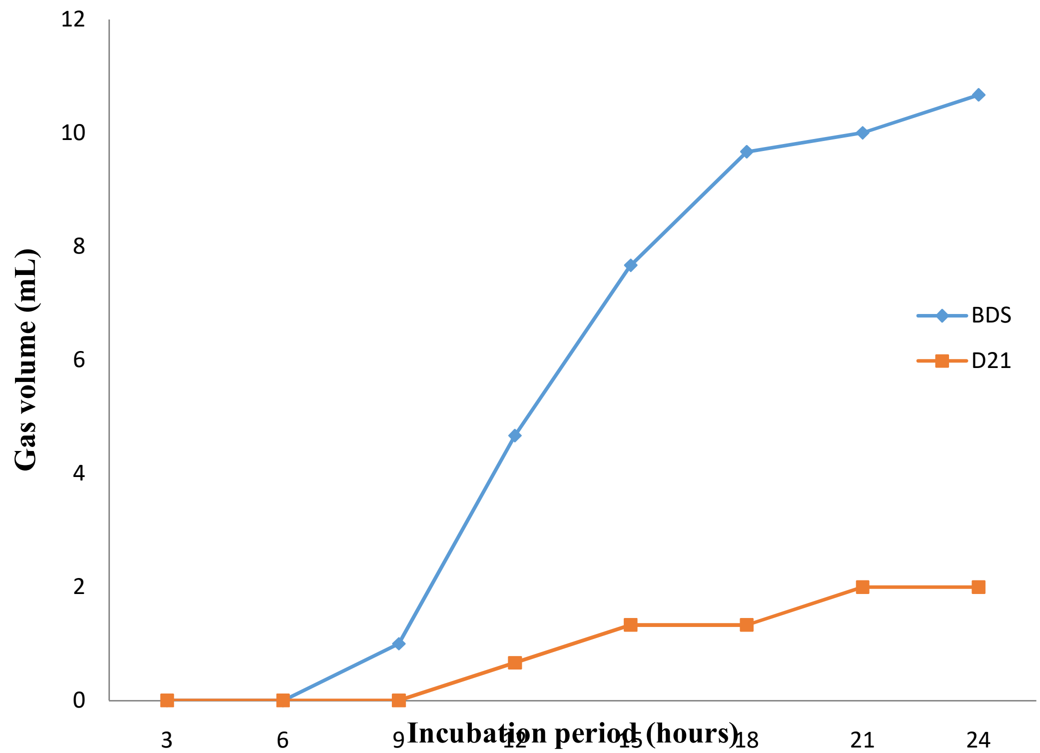

Figure 4.1: *In Vitro* gas production of Urea treated groundnut haulm at 24 hrs

UH: Untreated groundnut haulm,

TH: Urea treated groundnut haulm

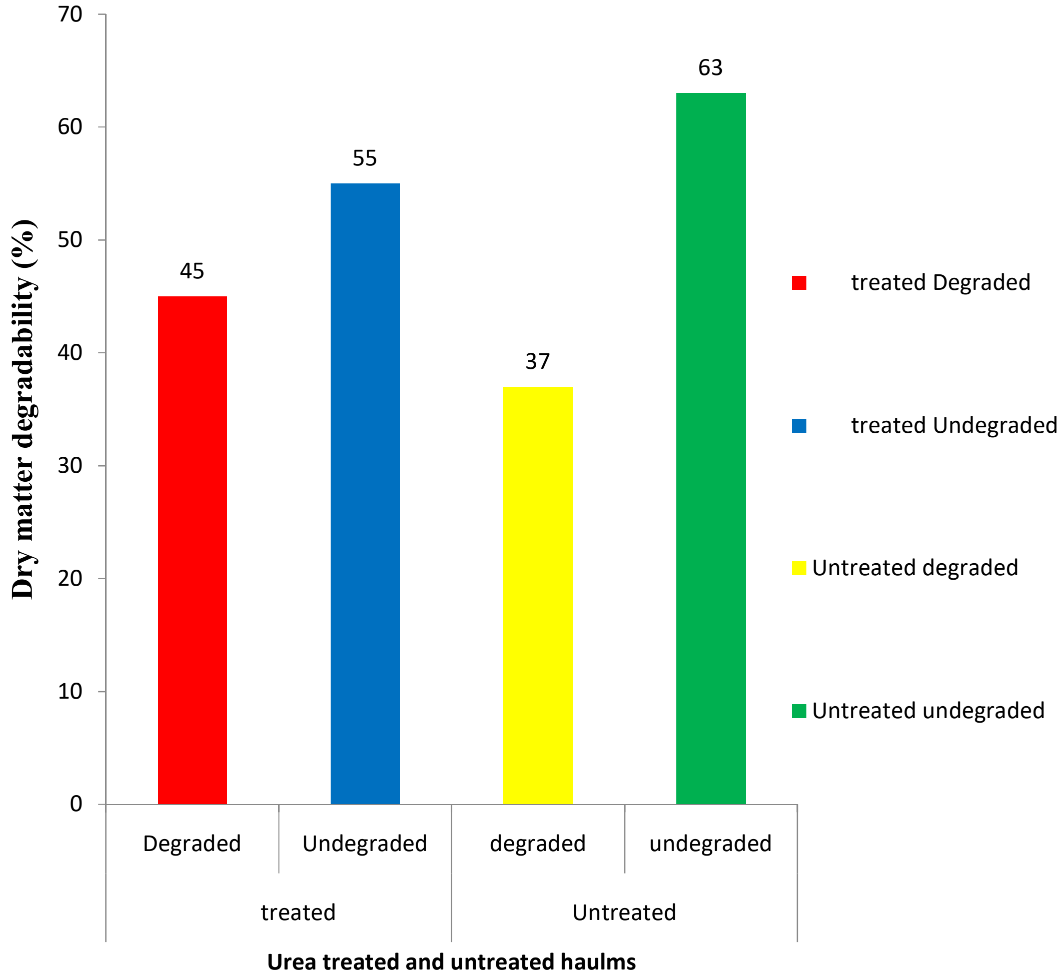

Fig 4.6: Dry matter degradability of urea treated and untreated groundnut haulms

Table 4.16: In vitro fermentation parameters of urea treated groundnut haulm at 24 hrs incubation period

Table 4.16 reveals the *in vitro* fermentation parameters of urea treated and untreated groundnut haulms at the 24 hour incubation period. There were no significant differences between the estimated parameters obtained in all the treatments. However, metabolisable energy (MJ/Kg DM), short-chain fatty acid (mmol/L) and organic matter digestibility (%) had higher numerical values of 4.83±0.34 MJ/Kg DM, 0.31±0.60 mmol/L, and 42.55±2.24 (%) respectively in urea treated groundnut haulm than the values of 3.56±0.28 MJ/Kg DM, 0.04±0.05 mmol/L and 33.46±1.85 (%) obtained in untreated groundnut haulm.

Figure 4.7 shows the graphical illustration of methane (CH_4) volume at 24 hours incubation period. It could be observed from the chart that methane produced was numerically higher (4.00 mL) in untreated groundnut haulm than (1.00 mL) obtained for urea treated groundnut haulm.

xTable 4.16: ***In vitro*** **fermentation parameters of urea treated groundnut haulm at 24 hours incubation period.**

Variable	Treatment		SEM	P-values
	UH	TH		
ME (MJ/KgDM)	3.56±0.28	4.83±0.34	1.30	0.812
SCFA (mmol/L)	0.04±0.05	0.31±0.60	0.20	0.612
OMD (%)	33.46±1.85	42.55±2.24	10.01	0.412

SEM= Standard Error of Means

UH= Untreated groundnut haulm

TH= Urea treated groundnut haulm

ME= Metabolisable energy

SCFA = Short chain fatty acids

OMD= Organic matter digestibility

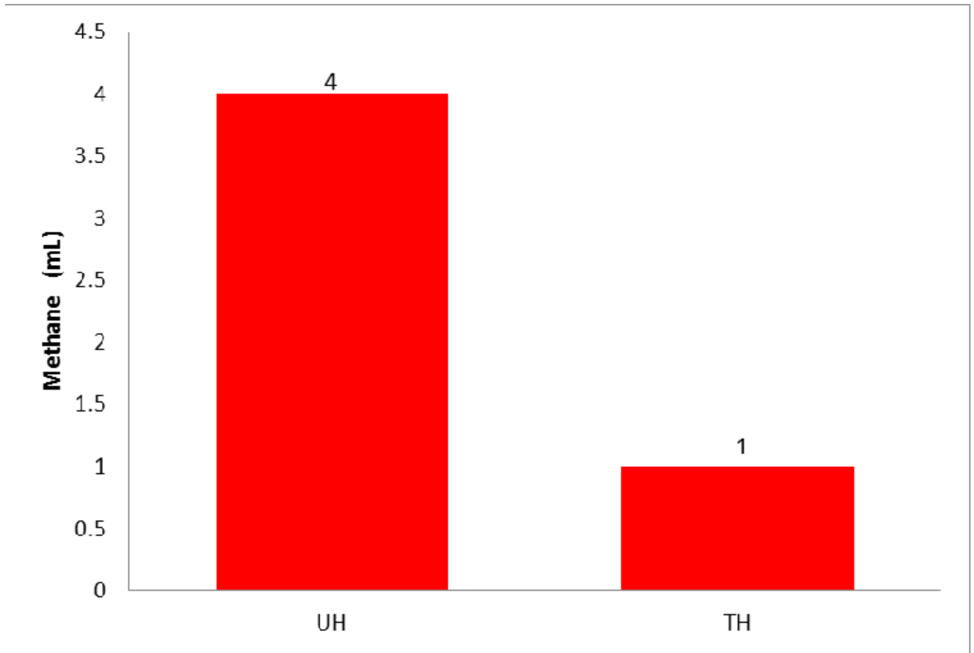

Figure 4.7: Methane production of urea treated and untreated groundnut haulm at 24hrs of incubation period

UH= Untreated groundnut haulm,

TH= urea treated groundnut haulm

4.3.2 *In vitro* gas production and fermentation characteristics of groundnut haulms from different locations at 24 hours incubation period.

Table 4.17 shows the gas production from the soluble fraction (a), the gas production from the insoluble but degradable fraction (b), potential gas production fraction (a+ b), gas production rate constant (c), incubation time (t) and Y which is the gas volume production at time t for 24 hours incubation period. There was no gas production from soluble fractions from groundnut haulms from all the locations. The volume of gas produced from 'b' for groundnut haulm from Akinyele (9.00±1.73 mL) and Bode Saadu (10.67±8.08 mL) was similar but lower ($P < 0.05$) than the gas volume of 15.33±2.52 mL from Ogbomoso. The potential gas production fraction (a+ b) of 15.33±2.52 mL for Ogbomoso was higher ($P < 0.05$) than 10.67±8.08 mL and 9.00±1.73 mL the values that are similar for Bode Saadu and Akinyele, respectively. The gas production rate constant (c) was similar ($P > 0.05$) among all the treatments. The incubation time‘t’ for Bode Saadu(15.00±0.00 hrs) and (14.00±1.73 hrs) Akinyele was similar ($P > 0.05$) but higher than (10.00±3.46 hrs) for Ogbomoso. The ’Y’ value ranged from 7.67±5.51 mL(Bode Saadu) to (9.33±6.03 mL) Akinyele and was similar across all the treatments.

Figure 4.8 represents the graphical illustration of *invitro* gas production of groundnut haulms collected from Akinyele, Bode Saadu, and Ogbomoso at the 24 hour incubation period. The graph reveals that gas production started earlier after 6 hrs of incubation for groundnut haulm from Ogbomoso compared to Bode Saadu and Akinyele which started producing gas after 9 hrs. The graph shows that groundnut haulm from Ogomoso had a higher numerical gas volume of 15.33 mL than 10.67 mL and 9.00 mL for Bode Saadu and Ogbomoso, respectively.

Table 4.17 : *In vitro* fermentation characteristics of groundnut haulms from different locations at 24 hrs incubation period

Location	Parameters					
	a(mL)	b(mL)	a+b(mL)	c(mLh^{-1})	t (hrs)	Y (mL)
AKY	0.00±0.00	9.00±1.73^{b}	9.00±1.73^{a}	0.15±0.04	14.00±1.73^{a}	9.33±6.03
BDS	0.00±0.00	10.67±8.08^{b}	10.67±8.08^{a}	0.14±0.03	15.00±0.00^{a}	7.67±5.51
OGB	0.00±0.00	15.33±2.52^{a}	15.33±2.52^{b}	0.26±0.14	10.00±3.46^{b}	9.32±2.31
SEM	0.00	2.00	3.20	0.10	2.46	1.12

a,b in the same column with different superscripts are significantly different ($p<0.05$). SEM= Standard Error of Mean. AKY= Akinyele Kraal Market, BDS= Bode Saadu, OGB= Ogbomoso

a - The gas production from the soluble fraction

b -The gas production from the insoluble but degradable fraction

a + b - Potential extent of gas production fraction

c - Gas production rate constant

t - Incubation time

Y - Gas volume production at time t

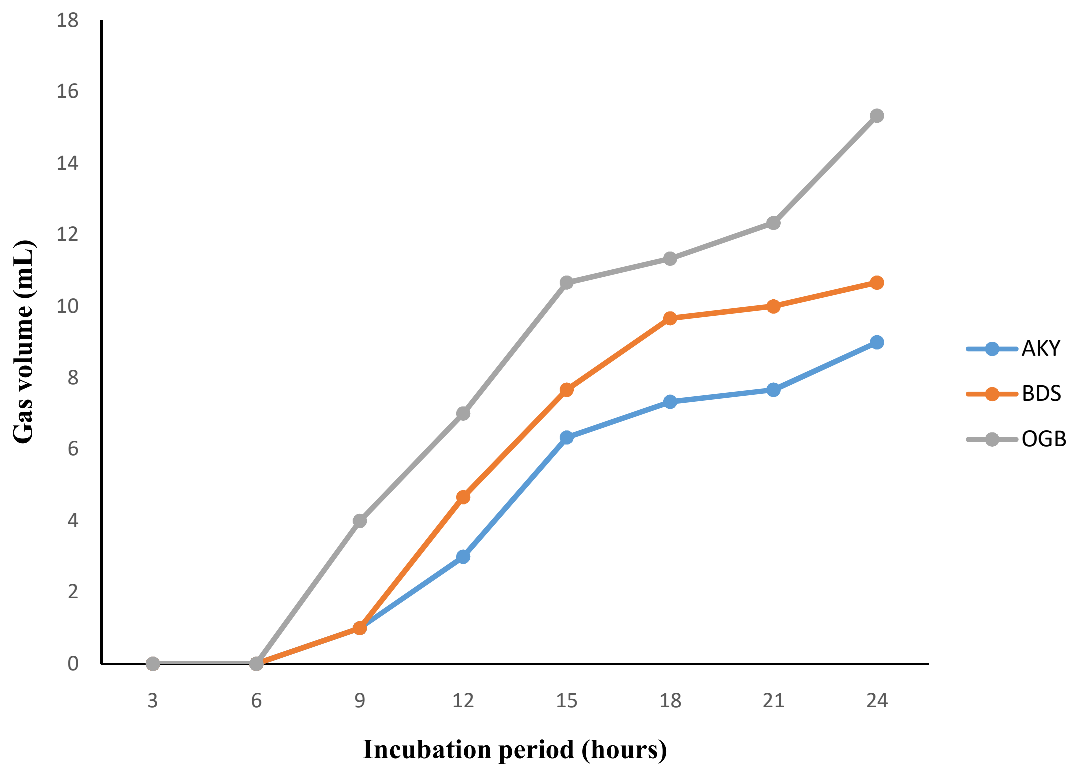

Figure 4.8*:* *In Vitro* gas production of groundnut haulms from different locations at 24 hour

AKY: Akinyele, BDS: Bode Saadu, OGB: Ogbomoso

4.3.3 *In vitro* gas production and fermentation characteristics of urea treated and pelleted groundnut haulms based diets at 24 hours incubation period.

Table 4.18 shows the *in vitro*fermentation characteristics of urea treated and pelleted groundnut haulm-based diets for 24 hours. There were no significant (P > 0.05) differences among the treatments for all the parameters considered. There was no gas produced from soluble fraction 'a'. The gas production forinsoluble but degradable fraction ('b') value ranged from 14.67±2.52 mL in D2 to 19.33±2.89 mL in D4. The highest numerical value of 19.33±2.89 mL for the potential extent of gas production (a+b) was observed in D4 and the lowest 15.67±3.79 mL in D3. The gas production rate constant ('c') ranged from -0.23±0.08 mLh^{-1} in D2 to -0.18±0.04mLh^{-1} in D3. The incubation time (t hrs) and volumes of gas (Y mL) at t was from 10.00±3.46 in D2 to 13.00±1.73 in D1 and 7.67±5.51 in D3 to 11.00±4.36 in D4 respectively.

Figures 4.9 and 4.10 presents the graphical illustrations of *invitro* gas production of treatments at 24 hours incubation period. The graph reveals that gas production started nearly at the same time, after 6hrs of incubation for all the treatments. The gas production of D2 was consistently at a faster rate and had higher values by D3. The D4 (Diet 4) started gas production at a lower rate and volume than D1 until after 12 hours of incubation when its gas production became faster and higher than D1. Figures 5 and 6 reveal that D2 had the highest numerical gas volume of 27 mL while D1 had the lowest of 12 mL at 24 hours incubation time.

Table 4.18: ***In Vitro*** **fermentation characteristics of urea treated and pelleted groundnut haulm based diets for 24 hours**

Treatment	Parameters					
	a (mL)	b (mL)	a + b (mL)	c (mL)	t (mL)	Y (mL)
D1	0.00±0.00	17.67±5.13	17.67±5.13	0.19±0.03	13.00±1.73	10.67±2.08
D2	0.00±0.00	14.67±2.52	14.67±2.52	0.23±0.08	10.00±3.46	8.00±2.65
D3	0.00±0.00	15.67±3.79	15.67±3.79	0.18±0.04	11.00±1.73	7.67±5.51
D4	0.00±0.00	19.33±2.89	19.33±2.89	0.21±0.04	12.00±3.00	11.00±4.36
SEM	0.00	0.10	1.00	0.05	0.05	0.03

D1= Untreated not pelleted , D2= Urea Treated not pelleted, D3= Untreated pelleted , D4= Urea Treated pelleted, SEM = standard error of the mean

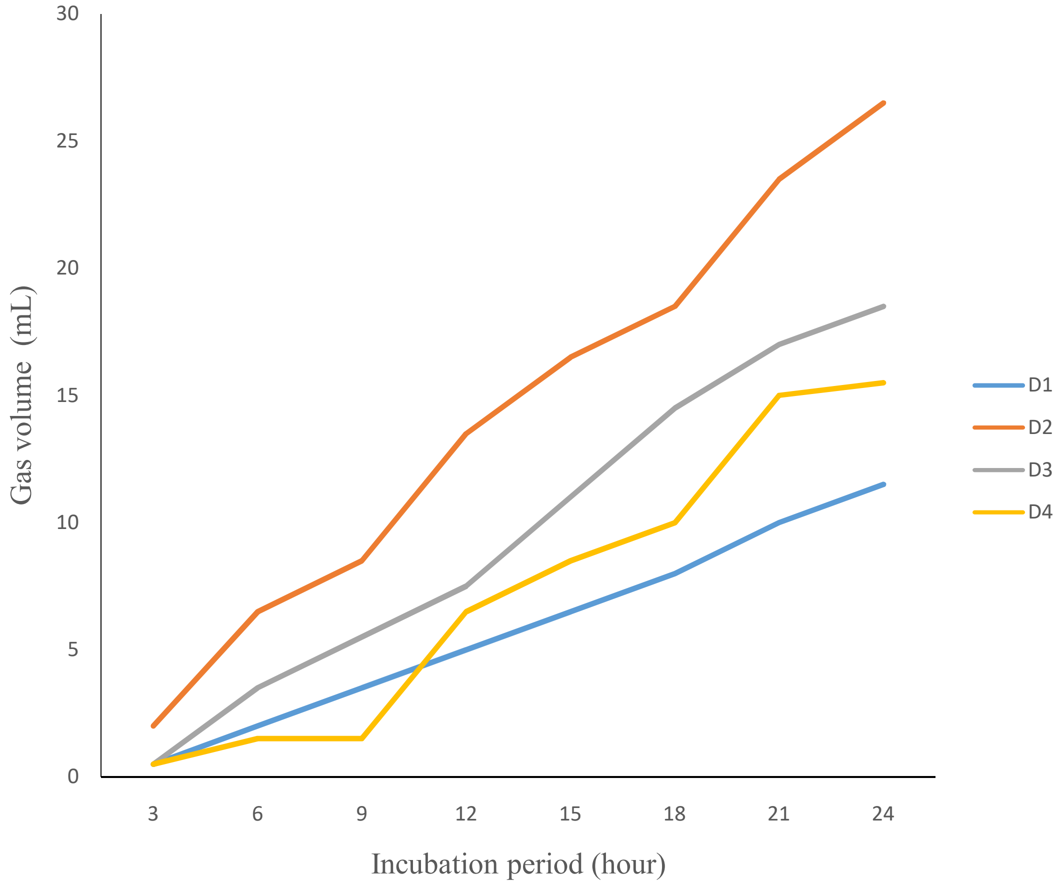

Fig 4.9 : *In vitro* gas production of treatments at 24 hours incubation period

D1= Untreated unpelleted

D2= Urea treated unpelleted

D3= Untreated pelleted

D4= Urea treated pelleted.

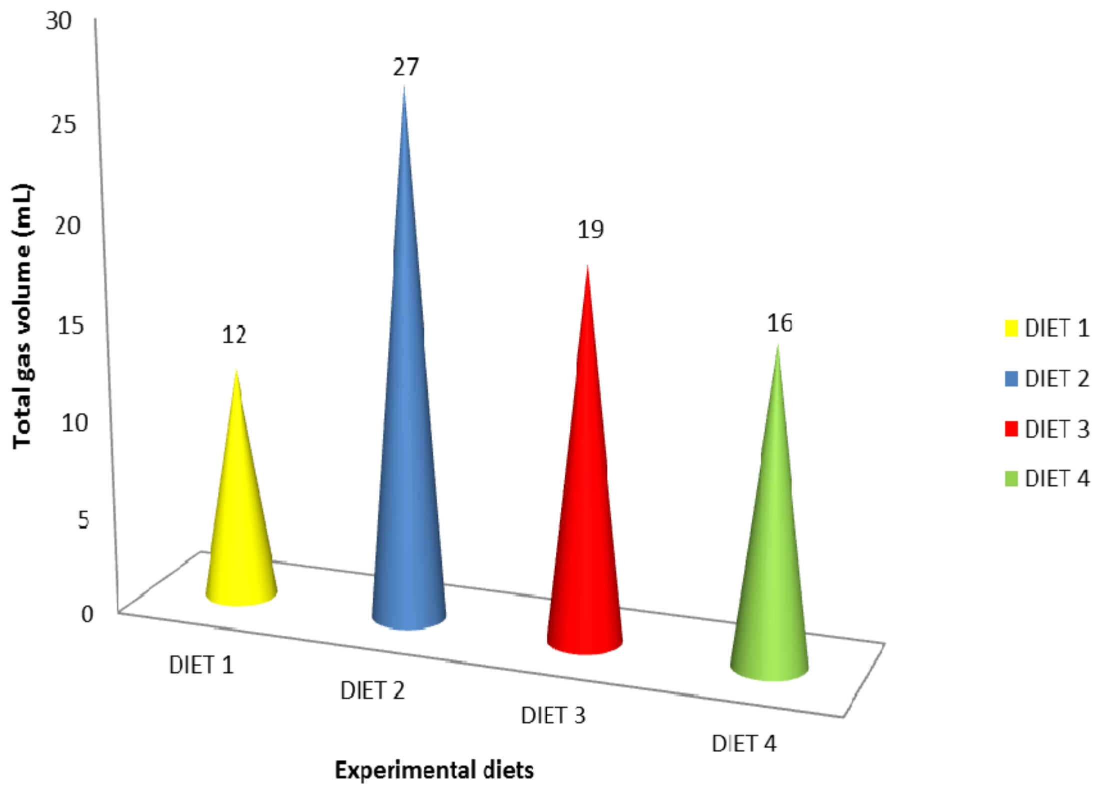

Fig 4.10: Total gas volume of treatments at 24 hour of incubation

DIET 1= Untreated not pelleted,

DIET 2= Urea Treated not pelleted,

DIET 3= Untreated pelleted,

DIET4= Urea Treated pelleted.

4.3.4 ***In vitro* fermentation parameters of urea treated and pelleted groundnut haulm based diets at 24 hrs incubation period**

Table 4.19 reveals the *in vitro* fermentation parameters and methane production of urea treated groundnut haulm-based diets at 24 hrs incubation period. There were no significant differences among the parameters observed in all the treatments. The Metabolisable energy ranged from 4.91±0.34 MJ/Kg DM in D2 to 5.55±0.39 MJ/Kg DM in D4. The SCFA (mmol/L) value of 0.40±0.07 was highest in D4 and the lowest (0.29±0.06) in D2. The organic matter digestibility was numerically higher in D4 (45.74±2.57%), D1 (43.56±4.56%), D2 (40.82±2.24%) and D3 (40.09±3.37%), respectively. The methane (CH_4) production values of 4.00±0.00 mL/200mg, 4.33±0.58 mL/200mg, 4.33±0.58 mL/200mg and 4.67±0.58 mL/200mg for D2, D1, D3 and D4 respectively was similar (P>0.05).

Table 4.19: *In vitro* fermentation parameters of urea treated and pelleted groundnut haulm based diets at 24 hrs incubation period

	Parameters			
Treatment	ME (MJ/Kg DM)	SCFA (mmol/L)	OMD (%)	CH_4 (mL/200mg)
D1	5.35±0.70	0.36±0.12	43.56±4.56	4.33±0.58
D2	4.91±0.34	0.29±0.06	40.82±2.24	4.00±0.00
D3	4.95±3.37	0.31±0.09	40.09±3.37	4.33±0.58
D4	5.55±0.39	0.40±0.07	45.74±2.57	4.67±0.58
SEM	0.15	0.03	4.95	0.14

ME= Metabolisable energy, SCFA = Short chain fatty acids, OMD= Organic matter digestibility, D1= Untreated not pelleted, D2= Urea Treated not pelleted, D3= Untreated pelleted, D4= Urea Treated pelleted, CH_4 = Methane gas, SEM = standard error of the mean

4.3.5 Rumen fermentation characteristics and microbial population in WAD rams fed urea treated groundnut haulm based pelleted diets

Table 4.20 shows rumen fermentation characteristics and microbial population of WAD rams fed urea treated groundnut haulms based pelleted diets. Pelleting had significant ($P < 0.05$) effects on all the parameters considered except the pH. Values for total volatile fatty acids (257.12 mmol/100 mL) and ammonia nitrogen (29.19%) for rams on pelleted diets were higher ($P<0.05$) than the values of 248.73 mmol/100mL and 24.96% respectively for animals fed diets that were not pelleted. Molar proportions of acetate (41.04%) and propionate (31.9 %) of animals allotted to pelleted diets were higher ($P<0.05$) compared to 41.68% and 31.14% respectively for those on diets not pelleted but the butyrate was similar. Acetate: propionate for animals on pelleted (1.29) was higher ($P<0.05$) than 1.34 for those on unpelleted diets and the ratio followed the same trend in animals allotted to urea treated and untreated diets respectively. Microbial counts of bacteria (3.17×10^8 CFU/mL), fungi (1.73×10^3 CFU/mL) and protozoa (2.91×10^3/mL) of animals on pelleted diets were higher ($P < 0.05$) than counts of 2.90×10^8 CFU/mL, 1.40×10^3 CFU/mL and 2.41×10^3/mL, respectively for those allotted to unpelleted diets.

Urea treatment follows a similar trend as in pelleting. There was no difference ($P > 0.05$) between pH values of 6.50 for animals on urea-treated diets and 6.65 for animals assigned to untreated diets. Total volatile fatty acids of 254.33 mmol/100mL and 27.60% for ammonia nitrogen in animals fed urea treated diets were higher ($P<0.05$) than 251.52 mmol/100mL and 26.55% respectively in those on untreated diets. Ruminal acetate (41.47%), propionate (31.41%) and butyrate (27.12%) in animals fed treated diets were greater ($P<0.05$) compared to acetate (41.23%), propionate (31.66%) and butyrate (27.16%) respectively in animals on untreated diets. The acetate: propionate for animals on treated (1.32) and those fed untreated diets (1.30) differs ($P < 0.05$). Ruminal fungi (1.64×10^3 CFU/mL) and protozoa (2.90×10^3 /mL) counts for treated diets were respectively higher ($P<0.05$) than 1.49×10^3CFU/ml and 2.48×10^3 /mL respectively for rams on untreated diets but the values for bacteria in treated diets (3.11×10^8 CFU/mL) and 2.96×10^8 CFU/mL for untreated diets were similar ($P> 0.05$).

Table 4.20: Main effects of urea treatment and feed forms on rumen fermentation characteristics and microbial population in WAD rams.

Treatment	Parameters									
	pH	TVFA (mMol/ 100ml)	NH_3-N (%)	Acet (%)	Prop (%)	Buty (%)	Ace: Pro	Bact (CFU/mL) X10[8]	Fungi (CFU/mL) X10[3]	Prot (/mL) X10[3]
Feed form										
Pelleted	6.54	257.12[a]	29.19[a]	41.04[a]	31.92[a]	27.04	1.29[b]	3.17[a]	1.73[a]	2.91[a]
Unpelleted	6.61	248.73[b]	24.96[b]	41.68[b]	31.14[b]	27.18	1.34[a]	2.90[b]	1.40[b]	2.47[b]
SEM	0.45	0.41	0.35	0.20	0.19	0.40	0.01	0.06	0.25	0.70
P-value	0.3460	0.0001	0.0001	0.0093	0.0001	0.0571	0.0001	0.0106	0.0001	0.0007
Urea treatment										
Treated	6.5	254.33[a]	27.60[a]	41.47[a]	31.41[a]	27.12[a]	1.32	3.11	1.64[a]	2.90[a]
Untreated	6.65	251.52[b]	26.55[b]	41.23[b]	31.66[b]	27.16[b]	1.30	2.96	1.488[b]	2.479[b]
SEM	0.05	0.40	0.34	0.21	0.18	0.37	0.01	0.07	0.03	0.08
P-value	0.0540	0.0001	0.0432	0.0001	0.0012	0.0269	0.1101	0.1520	0.0026	0.0011

a,b in the same column with different superscripts are significantly different ($p<0.05$), SEM= Standard Error of Mean, TVFA = Total Volatile Fatty Acid, Accet= Acetate, Prop = Propionate, Buty = Butyrate, Bact= Bacteria, Prot = Protozoa 1= Main effect of pelleting, 2 = Main effect of urea treatment, CFU = colony forming unit

4.3.6 Effects of the interaction of urea treatment and feed forms on rumen fermentation characteristics and microbial population in WAD rams

Effects of interaction of pelleting and urea treatment on rumen fermentation characteristics and microbial population in WAD rams are presented in Table 4. 21. Urea treatment x pelleting had no effect ($P>0.05$) on pH which ranged from 6.50 in D4 to 6.72 in D1. Ammonia-N values ranged in increasing order from 24.42%, 25.50%, 28.68% to 29.69% for D1, D2, D3 and D4 respectively and without urea treatment x pelleting effect. Urea treatment x pelleting had effect ($P<0.05$) on TVFA with highest value of 258.44 mmol/100mL in D3 and lowest in D1 (244.60 mmol/100mL). Ruminal acetate and butyrate values of 71.58% (D1), 72.62% (D3), 74.06% (D2), 74.76% (D4) and 46.46% (D1), 48.34% (D4), 48.34% (D3) and 48.54% (D2) respectively were not ($P>0.05$) affected by combined effect of urea treatment and pelleting. Urea treatment x pelleting had effect on ruminal propionate which ranged from 53.24% (D1), 55.58% (D2), and 57.16% (D4) to 57.50% (D3). Urea treatment x pelleting had no effect on ruminal microbial counts. Ruminal bacteria, fungi and protozoa ranged from 2.78 x 10^8 CFU/mL (D1) to 3.20 x 10^8 CFU/mL (D4), 1.31x 10^3 CFU/mL (D1) to 1.80 x 10^3 CFU/mL (D4) and 2.17 x 10^3 /mL (D1) to 3.04 x 10^3 /mL (D4), respectively.

Table 4.21: Effects of interaction of urea treatment and feed forms on rumen fermentation characteristics and microbial population in WAD rams

Parameters	Pelleted		Unpelleted		SEM	P- Values
	Untreated[3] D3	Treated[4] D4	Untreated[1] D1	Treated[2] D2		Interaction U x P
pH	6.58	6.5	6.72	6.50	0.07	0.35
NH_3 –N (%)	28.68	29.69	24.42	25.50	0.45	0.9408
TVFA (mMol/100L)	258.44	255.80	244.60	252.86	0.56	0.0001
Acetate (%)	72.62	74.76	71.58	74.06	0.29	0.5718
Propionate (%)	57.50	57.16	53.24	55.58	0.25	0.0001
Butyrate (%)	48.34	48.34	46.46	48.54	0.52	0.1323
Microbial population (cfu/ml)						
Protozoan (x 10^3/mL)	2.78	3.04	2.17	2.76	0.11	0.1366
Bacteria(x 10^8 cfu/mL)	3.15	3.20	2.78	3.02	0.10	0.3300
Fungi (x 10^3 cfu/mL)	1.66	1.80	1.31	1.48	0.04	0.6990

1= D1 (untreated unpelleted diet), 2= D2 (urea treated unpelleted diet), 3= D3 (untreated pelleted diet), 4 = D4 (urea treated pelleted diet), U x P – Interaction of Urea treatment x pelleting, SEM = Standard Error of Means. CFU= Colony forming unit

4.4.0 Study Four: Performance, nutrient digestibility, and nitrogen utilisation of WAD rams fed urea treated groundnut haulm based pelleted diets.

4.4.1 Main effects of urea treatment and feed forms on growth performance of WAD rams

Table 4.22 shows the daily weight gain, daily dry matter intake (DMI), feed conversion ratio (FCR), and feed cost per kilogramme gain of WAD rams fed urea treated groundnut haulm based pelleted diets. Pelleting had significant ($P < 0.05$) effects on DWG and FCR. Pelleted feeds had a higher ($P < 0.05$) value of 46.31 g/d compared to 21.59 g/d for rams fed unpelleted diets. Animals on pelleted diets had better efficiency of feed utilisation than those allotted to unpelleted diets as indicated by the values of feed conversion ratio of 12.00 and 13.30 for animals on pelleted and unpelleted diets respectively. The value of DMI for pelleted diets (547.09 g/d) was similar ($P>0.05$) to 462.00 g/d for rams on diets that were not pelleted.

Urea treatment elicited better effect on feed utilisation by the animals as shown by lower ($P<0.05$) value of feed conversion ratio of 12.26 for the rams on urea treated diets compared to 13.30 for those fed untreated diets. DWG (g/d) ranged between (36.75g/d and 31.15g/d) and for rams on treated and untreated diets respectively. The DMI (g/d) ranged between 482.63 g/d and 526.46 g/d for animals allotted to untreated and untreated diets respectively and were similar ($P>0.05$)

Table 4.22: The main effects of urea treatment and feed forms on growth performance of WAD rams

	Parameters					
Treatment	IW/ Kg	FW/Kg	WG/Kg	DWG g/d	DMIg/d	FCR
Feed form						
Pelleted	9.25	14.11	4.86[a]	46.31[a]	547.09	12.00[b]
Unpelleted	12.50	15.06	2.267[b]	21.59[b]	462.00	13.30[a]
SEM	1.60	1.34	0.56	6.20	30.30	0.10
P-values	0.2835	0.6330	0.0187	0.0187	0.0744	0.0001
Treated	8.50	12.79	3.85	36.75	482.63	12.26[b]
Untreated	13.70	16.41	3.27	31.15	526.46	13.03[a]
SEM	1.57	1.27	0.66	6.24	30.20	0.11
P-values	0.774	0.1131	0.5402	0.5403	0.329	0.0011

[a,b] Mean in the same column with different superscripts are significantly different ($p<0.05$), IW = Initial weight, FW = Final weight, WG = Weight gain, DWG = Daily weight gain, FCR= Feed conversion ratio, DMI= Dry Matter Intake, SEM= Standard Error of Means, W= Weight.

4.4.2 Effects of Interaction of urea treatment and feed forms on growth performance of WAD rams fed urea treated groundnut haulm based pelleted diets

Table 4.23 reveals the effects of the interaction of urea treatment and pelleting on the performance of WAD rams fed urea treated groundnut haulm based pelleted diets. Urea treatment x pelleting had effects on weight gain, DWG, and FCR. Weight gain and daily weight gain followed the same trend. Weight gain was highest (5.15 kg) in animals on urea treated pelleted diet (D4) and lowest (1.97 kg) in rams allotted untreated unpelleted diet (D1). Daily weight gain values of 49.05g/d were highest for animals on urea treated pelleted diet (D4) and lowest values of 18.73 g/d for rams allotted untreated unpelleted diet (D1). FCR of 13.79 was highest in D2 and lowest (10.74) in D4. Dry matter intake increased from 450 g/d (D2), 474.00 g/d (D1), and 512.25 g/d (D4) to 578.93 g/d (D1) and was not affected by the synergy of urea treatment and pelleting.

Table 4.23: Effects of Interaction of urea treatment and feed forms on growth performance of WAD rams fed urea treated groundnut haulm based pelleted diets

Parameters	Pelleted		Unpelleted		SEM	P- Values
	Untreated[3] D3	Treated[4] D4	Untreated[1] D1	Treated[2] D2		Interaction U X P
Initial weight (kg)	9.25	9.25	10.75	9.75	1.22	0.7527
Final weight (kg)	13.82	14.40	12.72	12.32	1.792	0.5239
Weight gain (kg)	4.57	5.15	1.97	2.57	0.858	0.0395
Daily Wt. gain (g/d)	43.57	49.05	18.73	24.44	8.16	0.0048
DM Feed Intake (g/d)	578.93	515.25	474.00	450.00	39.55	0.6523
FCR	13.26	10.74	12.81	13.79	0.158	0.001

[a,b,c] Means in the same row with different superscripts are significantly different ($p<0.05$) FCR= Feed Conversion Ratio, DM = Dry Matter, 1= D1 (untreated unpelleted diet), 2= D2 (urea treated unpelleted diet), 3= D3 (untreated pelleted diet), 4 = D4 (urea treated pelleted diet), U x P - Interaction of Urea treatment x pelleting

4.4.3Main effects of urea treatment and feed forms on the cost-benefit of feeding WAD rams urea treated groundnut haulm based pelleted diets

Table 4.24 shows the cost per kg feed, total feed intake (kg), total weight gain (kg), total feed cost (₦), cost per kg weight gain (₦), the total cost of production /kg (₦), price per kg mutton (₦) and gross or profit margin (₦) of feeding urea treated based pelleted diets to WAD rams. Pelleting had a significant (P<0.05) effect on all the parameters considered. Cost/kg of pelleted diet (N70.62) was higher (P<0.05) than the cost/kg feed of the unpelleted diet (N40.91). Similarly, animals on pelleted diets consumed more feed (57.45kg), gain more weight (4.86kg), and incurred higher total feed cost (N4042.77) compared to 48.51kg, 2.27kg, and N2028.92 respectively for rams fed unpelleted diets. Feed conversion ratio value of 12.00 for animals on pelleted diets was lower than 13.30 for those on unpelleted diets. The monetary value of weight gain (N9720.00) for animals on pelleted diets was higher than (N4540.00) for the animals fed unpelleted diets. The net benefit of N5677.23 for animals on pelleted diets was higher than N2511.08 for those allotted to unpelleted diets.

Table 4.24: Main effects of urea treatment and pelleting on the cost-benefit of feeding WAD rams urea treated groundnut haulm based pelleted diets

	Parameters						
Treatment	FC ₦/Kg	TFIKg	WG Kg	TFC (₦)	Cost/kg mutton (₦)	MVWG (₦)	NtB (₦)
Feed form							
Pelleted	70.62[a]	57.45[a]	4.86[a]	4042.77[a]	2000.00	9720[a]	5677.23[a]
Unpelleted	40.91[b]	48.51[b]	2.27[b]	2028.92[b]	2000.00	4540[b]	2511.08[b]
SEM	0.41	30.20	0.66	123.00	1.00	268.75	40.00
P-values	0.0001	0.0074	0.0187	0.0023	0.8600	0.0024	0.0031
Urea treatment							
Treated	59.79[a]	50.67	3.85	3080.39	2000.00	7700	4619.61
Unreated	51.75[b]	55.28	3.27	2991.78	2000.00	6540	3548.22
SEM	4.41	8.20	0.66	50.41	1.00	30.40	92.44
P-values	0.0001	0.329	0.5402	0.6541	0.8600	0.431	0.5211

1= D1 (untreated unpelleted diet), 2= D2 (urea treated unpelleted diet), 3= D3 (untreated pelleted diet), 4 = D4 (urea treated pelleted diet), U x P - Interaction of Urea treatment x pelleting 3- Urea treatment x pelleting interaction, = Nigeria Naira. FC= Feed cost, DMI = Dry matter intake, WG= Weight gain, TFC = Total feed cost, MVWG = monetary value of weight gain, NtB= Net benefit, ₦ = Nigeria naira.

4.4.4 Effects of the interaction of urea treatment and pelleting on cost-benefit of feeding WAD rams urea treated groundnut haulm based pelleted diets

Table 4.25 reveals the cost-benefit of urea treated x pelleted groundnut haulm diets to WAD rams. Urea treatment x pelleting had effects ($P<0.05$) on weight gain (WG) (kg), total feed cost (TFC), the monetary value of weight gain (MVWG), and net benefit (NtB) amongst the parameters considered. Weight gain value of 5.15kg was highest in D4 (treated pelleted diet) and lowest (1.97 kg) in D1 (untreated unpelleted diet). The total feed cost value of ₦4042.53 was highest in animals fed (D3) and lowest value of ₦1941.03 in D1. MVWG ranged from ₦3940.00 (D1), ₦5140.00 (D2), ₦9140.00 (D3) and ₦10300.00 (D4). Net benefit of ₦6256.02 was highest in D4 and lowest ₦1998.97 in D1. However, a combination of urea treatment and pelleting had no effects ($P>0.05$) on feed cost (FC) and DMI of the rams fed the experimental diets. FC and DMI values ranged from ₦39.00/kg (D1) to ₦74.75/kg (D4) and 47. 22 kg (D2) to 60.79 kg (D3) respectively.

Table 4.25: Effects of interaction of urea treatment and pelleting on cost-benefit of feeding WAD rams urea treated groundnut haulm based pelleted diets

Parameters	Pelleted		Unpelleted		P- values	
	Untreated[3]	Treated[4]	Untreated[1]	treated[2]	SEM	Interaction
	D3	D4	D1	D2		U X P
FC (N)/Kg	66.5	74.75	39.00	44.8	0.55	0.7311
DMI (Kg)	60.79	54.10	49.77	47.25	39.55	0.6523
WG (kg)	4.57	5.15	1.97	2.57	0.86	0.0395
TFC (N)	4042.53	4043.98	1941.03	2116.8	1.28	0.0421
MVWG (N)	9140.00	10300.00	3940.00	5140.00	230.78	0.0022
Price/Kg mutton (N)	2000.00	2000.00	2000.00	2000.00	1.00	1.000
NtB (N)	5097.47	6256.02	1998.97	3023.2	200.00	0.0024

1= D1 (untreated unpelleted diet), 2= D2 (urea treated unpelleted diet), 3= D3 (untreated pelleted diet), 4 = D4 (urea treated pelleted diet), U x P - Interaction of Urea treatment x pelleting 3- Urea treatment x pelleting interaction, N = Nigeria Naira, FC= Feed cost, DMI = Dry matter intake, WG= Weight gain, TFC = Total feed cost, MVWG = monetary value of weight gain, NtB= Net benefit.

4.4.5 Apparent nutrient digestibility in WAD rams fed urea treated groundnut haulm based pelleted diets.

The nutrient digestibility of WAD rams fed urea treated groundnut haulm-based pelleted diets are presented in Table 4.26. Feeding pelleted diets lowered ($P < 0.05$) apparent digestibilities (%) of dry matter (DM), crude protein (CP), and acid detergent lignin (ADL). Digestibility values ranged from 70.62% to 73.75%, 77.99% to 83.24%, and 54.80% to 64.66% for DM, CP, and ADL in pelleted and unpelleted diets respectively. However, OM, EE, CF, and hemicellulose digestibilities ranged from 67.69% to 71.02%, 83.29% to 83.59%, 64.59% to 67.78%, and 64.07% to 68.40% for pelleted and unpelleted diets respectively and were similar ($P>0.05$). Cellulose digestibility ranged from 79.26% to 80.55% in unpelleted and pelleted diets respectively. Acid detergent fibre digestibility of 72.13% for unpelleted diet was higher ($P<0.05$%) than 68.10% of the unpelleted.

Urea treatment elicited similar ($P > 0.05$) results in the digestibility of all nutrients evaluated. The dry matter digestibility ranged between 72.13% and 72.24% for animals on treated and untreated diets respectively. Also, the crude fibre digestibility ranged between 66.29% and 66.08% for rams fed treated and untreated diets respectively. Neutral detergent fibre digestibility ranged between 69.00% and 69.59% in rams allotted to urea treated and untreated diets respectively. The ADF digestibility ranged between 69.89% and 70.33% in animals fed untreated and urea treated diets respectively. Also, ADL digestibility ranged between 59.56% and 59.89% for rams on untreated and treated diets respectively. Cellulose digestibility ranged between 79.97% and 79.84% in rams fed urea treated and untreated diets respectively.

Table 4.26: Main effects urea treatment and feed forms on apparent digestibility (%) in WAD rams fed urea treated groundnut haulm based pelleted diets.

	Parameters (%)									
Treatment	DM	OM	CP	EE	CF	NDF	ADF	ADL	Hemi	Cellulo
Feed form										
Pelleted	70.62[b]	67.69	77.99[b]	83.29	64.59	67.26	68.10[b]	54.80[b]	64.07	80.55
Unpelleted	73.75[a]	71.02	83.24[a]	83.59	67.78	71.33	72.13[a]	64.66[a]	68.40	79.26
SEM	1.03	1.20	0.81	0.64	1.52	0.65	1.33	1.39	2.42	1.58
P-value	0.0494	0.0628	0.0001	0.750	0.1627	0.0353	0.0493	0.0001	0.2196	0.5754
Urea treatment										
Treated	72.24	68.74	80.66	83.15	66.29	69.00	70.33	59.89	64.34	79.97
Unreated	72.13	69.96	80.57	83.68	66.08	69.59	69.89	59.56	68.12	79.84
SEM	1.04	1.18	0.75	0.74	1.54	0.75	1.34	1.41	2.40	1.60
p-values	0.9482	0.4731	0.9404	0.615	0.924	0.7454	0.8193	0.8672	0.2807	0.954

[a,b,c] Means in the same column with different superscripts are significantly different (p<0.05), DM= Dry Matter, OM= Organic Matter, CP = Crude Protein, EE= Ether Extract, CF = Crude Fibre, NFE = Nitogen Free Extract, NDF= Neutral Detergent Fibre, ADF = Acid Detergent Fibre, ADL= Acid Detergent Lignin, SEM= Standard Error of Means, Wt= Weight, Hemi= Hemicellulose, Cellulo= Cellulose.

4.4.6Effects of Interaction of urea treatment and pelleting on apparent digestibility in WAD rams fed urea treated groundnut haulm based pelleted diets

Interaction of urea treatment and pelleting on apparent digestibility in WAD rams fed urea treated groundnut haulm based pelleted diets.

Table 4.27shows interaction effects of urea treatment and pelleting on apparent digestibility in WAD rams fed urea treated groundnut haulm based pelleted diets. Treatment x pelleting interactions were observed for acid detergent lignin (ADL), nitrogen-free extract (NFE), and ether extract (EE) amongst the parameters considered. ADL digestibility ranged from 56.94% (D3), 62.17% (D1), 62.64% (D4) and 67.14% (D2). NFE digestibility was highest at 49.95% in treated unpelleted diet (D2) and lowest in treated pelleted diet (D4). EE digestibility ranged from 81.53% (D4), 82.41% (D1), and 84.77% (D2) to 84.96% (D3).

Urea treatment x pelleting had no effects on digestibilities of dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and crude fibre (CF). DM and OM digestibilities ranged from 70.48% (D4), 70.77% (D3), 73.51% (D1) to 73.99% (D2) and 66.38% (D4), 69.00% (D3), 70.93% (D1) and 71.10% (D2) respectively. NDF and ADF digestibilities followed the same trend and values were from 65.92% (D4), 68.59% (D3), 70.58% (D1) to 72.09% (D2) and 67.12% (D4), 69.06% (D3), 70.72% (D1) to 73.54% (D2) respectively. Hemicellulose and cellulose digestibilities were not affected by urea treatment x pelleting and ranged from 61.52% (D4), 66.62% (D3), 67.17% (D2) to 69.34% (D1) and 78.71% (D1), 79.81% (D2), 80.13% (D4) to 80.96% (D3) respectively.

Table 4.27: Effects of Interaction of urea treatment and pelleting on apparent digestibility in WAD rams fed urea treated groundnut haulm based pelleted diets

Parameters (%)	PELLETED		UNPELLETED			P- Values
	Untreated[3] D3	Treated[4] D4	Untreated[1] D1	Treated[2] D2	SEM	Interaction U x P
Dry matter	70.77	70.48	73.51	73.99	1.47	0.7996
Organic matter	69.00	66.38	70.93	71.10	1.66	0.4135
Crude protein	78.06	77.94	83.10	83.37	1.05	0.8533
Ether extract	84.96	81.53	82.41	84.77	1.05	0.0140
Crude fibre	64.77	64.42	67.40	68.16	2.18	0.8019
NFE	49.69	46.09	49.87	49.95	0.60	0.0070
NDF	68.59	65.92	70.58	72.09	1.78	0.256
ADF	69.06	67.12	70.72	73.54	1.90	0.2289
ADL	56.94	62.64	62.17	67.14	1.99	0.0332
Hemicellulose	66.62	61.52	69.34	67.17	3.40	0.7030
Cellulose	80.96	80.13	78.71	79.81	2.25	0.6722

[a,b,c] Means in the same column with different superscripts are significantly different ($p<0.05$), NFE = Nitogen Free Extract, NDF= Nitrogen Detergent Fibre, ADF = Acid Detergent Fibre, ADL= Acid Detergent Lignin, SEM= Standard Error of Means, 1= D1 (untreated unpelleted diet), 2= D2 (urea treated unpelleted diet), 3= D3 (untreated pelleted diet), 4 = D4 (urea treated pelleted diet), U x P = Interaction of Urea treatment x pelleting

4.4.7 Nitrogen utilisation in WAD rams fed urea treated groundnut haulm based pelleted diets

Table 4.28 shows the main effect of urea treatment and pelleting on nitrogen utilisation and microbial protein synthesis by WAD rams fed urea treated groundnut haulm based pelleted diets. Rams fed pelleted diets had a lower (P<0.05) nitrogen intake value of 23.79 g/d compared to 26.96 g/d in animals fed diets that were not pelleted. Nitrogen faecal output of 5.23 g/d observed for animals on pelleted diets was higher (P < 0.05) than 4.48 g/d for those on diets that were not pelleted. The urinary nitrogen, faecal nitrogen, and total nitrogen excreted followed the same trend. The value of urinary nitrogen in rams fed pelleted diets (0.94 g/d) was higher than 0.80g/d obtained for those allotted to unpelleted diets. Also, the nitrogen value of 6.17g/d for animals on pelleted diets was higher than 5.28 g/d in animals fed diets that were not pelleted. The nitrogen balance and nitrogen retention followed the same trend. Nitrogen balance and nitrogen retention values of 17.62g/d and 74.00% respectively for animals fed pelleted were lower (P<0.05) than 21.68g/d and 80.24% for those allotted to unpelleted diets. The microbial protein synthesis for rams fed pelleted diets (5.81g/day) was similar (P> 0.05) with those fed unpelleted (5.17g/day).

Urea treatment had effects (P<0.05) only in urinary nitrogen (UN) and microbial protein synthesis (MPS). Urinary nitrogen of 0.96 g/d for animals fed untreated diet was higher than 0.79 g/d for rams on treated diets. However, the MPS of 5.85 g/d for animals on urea-treated diets was higher (P<0.05) than 5.17 g/d for those fed untreated diets. Urea treatment was similar (P>0.05) for nitrogen intake (NI), Faecal nitrogen (FN), nitrogen excreted (NE), Nitrogen balance (NB), and nitrogen retention (NR). Nitrogen intake and faecal nitrogen ranged between (24.60 and 26.15g/d) and (4.70 and 5.00g/d) for rams fed untreated and urea treated diets respectively. Also, total NE and NB ranged between (5.66 and 5.79g/d) and (18.93 and 20.36g/d) for animals allotted to untreated diets and those on diets that were treated respectfully. NR ranged between 76.61 and 77.64% for animals on untreated and urea-treated diets respectively.

Table 4.28: Main effect of urea treatment and pelleting on nitrogen utilisation and microbial protein synthesis by WAD rams fed urea treated groundnut haulm based pelleted diets

	Parameters						
Treatment	NI (g/d)	FN (g/d)	UN (g/d)	NE (g/d)	NB (g/d)	NR (%)	MPS g/day
Feed form							
Pelleted	23.79[b]	5.23[a]	0.94[a]	6.17[a]	17.62[b]	74.00[b]	5.81[a]
Unpelleted	26.96[a]	4.48[b]	0.80[b]	5.28[b]	21.68[a]	80.24[a]	5.17
SEM	0.78	0.16	0.04	0.75	0.81	0.90	0.81
P-values	0.0078	0.0059	0.0481	0.0044	0.0009	0.0001	0.0026
Urea trt							
Treated	26.15	5.00	0.79[b]	5.79	20.36	77.64	5.17
Untreated	24.60	4.70	0.96[a]	5.66	18.93	76.61	5.80
SEM	0.74	0.17	0.05	0.19	0.71	0.82	0.71
P-values	0.1553	0.2249	0.0187	0.6458	0.1741	0.3838	0.2160

[a,b,c] Means in the same column with different superscripts are significantly different ($p<0.05$), SEM= Standard Error of Means, trt = treatment, NI = Nitrogen intake, FN = Faecal nitrogen, UN = Urinary nitrogen, TNE = Nitrogen execreted, NB = Nitrogen balance, NR = Nitrogen retntion, MPS = Mirobial protein synthesis

4.4.8 Effects of Interaction of urea treatment and pelleting on nitrogen utilisation in WAD rams fed urea treated groundnut haulm based pelleted diets

Table 4.29 reveals the effects of the interaction of urea treatment and pelleting on nitrogen intake, faecal nitrogen, urinary nitrogen, total nitrogen excretion, nitrogen balance, and nitrogen retention in WAD rams fed urea treated groundnut haulm based pelleted diets. Urea treatments x pelleting had no (P>0.05) effect on all the parameters considered. Nitrogen intake (NI) ranged between 22.60 g/d and 27.31 g/d in rams fed untreated pelleted diet (D3) and urea treated unpelleted diets (D2) respectively. Urinary nitrogen ranged between 0.73 g/d in D2 and 1.04 in D3. Faecal nitrogen ranged from 4.45 g/d in unpelleted untreated diet (D1), 4.50 g/d (D2), 4.96 g/d (D3), and 5.50 g/d for treated pelleted diet (D4). Nitrogen excreted ranged from 5.23 g/d (D2), 5.32 g/d (D1), 5.60 g/d (D3) and 6.34 g/d (D4). Nitrogen balance ranged between 16.58 g/d (D3) and 22.08 g/d (D2). Nitrogen retention and nitrogen absorbed followed a similar pattern and ranged from 73.4% (D3) to 80.72% (D2) and 16.58% (D3) to 22.80% (D2) respectively. Microbial protein synthesis ranged from 5.04 g/d (D2), 5.29 g/d (D1), 5.30 g/d (D4), and 6.31 g/d (D3).

Table 4.29: Effects of Interaction of urea treatment and pelleting on nitrogen utilisation and microbial protein synthesis by WAD rams fed urea treated groundnut haulm based pelleted diets

Parameters	Pelleted		Unpelleted			P-value
	Untreated[3] D3	Treated[4] D4	Untreated[1] D1	Treated[2] D2	SEM	U x P
Nitrogen intake (g/d)	22.60	25.00	26.60	27.31	1.04	0.4233
Faecal nitrogen (g/d)	4.96	5.50	4.45	4.50	0.24	0.3205
Urinary nitrogen (g/d)	1.04	0.84	0.88	0.73	0.07	0.7200
Total nitrogen excreted (g/d)	6.00	6.34	5.32	5.23	0.27	0.4300
Nitrogen balance (g/d)	16.58	18.65b	21.29	22.08	1.01	0.5341
Nitrogen retention (%)	73.4	74.57	79.78	80.72	1.15	0.9350
Nitrogen absorbed (g/d)	16.58	18.65b	21.28	22.08	1.015	0.5350
MPS (g/d)	6.31	5.30	5.29	5.04	1.240	0.6321

1= D1 (untreated unpelleted diet), 2= D2 (urea treated unpelleted diet), 3= D3 (untreated pelleted diet), 4 = D4 (urea treated pelleted diet), U x P - Interaction of Urea treatment x pelleting, MPS = Microbial protein synthesis.

CHAPTER FIVE

DISCUSSION

Study one: Assessment of groundnut production and haulm use in Morro and Ogbomoso LGAs of Kwara and Oyo States, respectively.

The majority of the groundnut farmers (80%) from the study areas were males. This result agrees with the findings of Olafadehan and Adewumi (2011) that reported male dominance in crop-livestock production systems in Derived savannah. This may be attributed to the predominance of the traditional system of crop production which is drudgery, stressful, and requires physical strength that may be difficult for the women to cope with.

The dominance age range of 21-60 years obtained in the present study contradicts the reports of Chah *et al*. (2013) and Gebreegziabher *et al*. (2016) that reported the age bracket of 35 - 45 years category for the crop-livestock production system in derived guinea savannah. This may be due to better awareness of prospect in groundnut production for both the youth and adults in the study area, although fewer youths were involved in groundnut production in Morro Local Government compared to Ogbomoso probably because of 'Okada' (motorcycle) business which may be more lucrative in the area. It may also be as a result of the relatively higher literacy level of farmers in Ogbomoso which possibly prompted them to prefer a less ‘life risky’ or more dignified profession, and their better understanding of benefits in agriculture compared to those from Morro.

A large proportion of the groundnut farmers (96.7%) in the study locations were married. This may be due to the early income-generating nature of arable crops enterprise which probably encourages them to start a family life and settle down at early age as compared to professions that require a longer year of academic training to secure a job. Most of the farmers (78.4%) in the study areas embraced farming as their major occupation. This may be attributed to the agrarian background of the people in the studied area and their awareness of a better future in agribusiness, as the nation expects a paradigm shift in the economy from petroleum or crude oil to agricultural production.

The literacy level among the respondents was generally low, this is in consonant with the findings of Fakoya (2002) and Ayuk *et al*. (2011) that reported low literacy levels among farmers involved in the crop-livestock production system. It can be attributed to the general belief that farming is meant for the uneducated in society. The household size of farmers from Morro was higher than Ogbomoso possibly because farmers from Morro cultivated more land compared to their counterparts from Ogbomoso The need for more hands-on the farm as the production is still traditional or manual also explained higher average house hold size for groundnut farmers in Morro where production was higher compared to Ogbomoso of lower groundnut production capacity.

The average yield of between 1-2 tonnes per hectare recorded by the farmers is slightly higher than 0.9 tonne/ha reported by ICRISAT, (2015) among the traditional groundnut farmers, this may be due to new cultivars available to farmers in recent times. However, the groundnut farmers from Morro had relatively higher productivity than Ogbomoso. This might be as a result of better environmental factors (soil, water, or temperature) in the Guinea savannah and management or cultural practices by the farmers. Groundnut production is more abundant in the drier region of Nigeria (ICRISAT, 2015).

All the respondents cultivated groundnut during the rainy season only. This may be due to a lack of irrigation facilities during the dry season for crop production. The study also reveals that farmers in the study locations depended more on friends and family and in Morro (56.7%) and Ogbomoso (50%) as the main source of finance for the farming and followed by personal savings. This may be the reason for the low farm size of an average of 1-2 ha by the majority of the farmers from the two locations. On average, the two major sources of labour available to the farmers were hired (55%) and family (45%), this may be probably due to medium-size production capacity that might not necessarily require the use of mechanisation.

The five major problems identified by the farmers were drought, pest/diseases, labour availability, animal invasion, and inadequate finance. This is partially in agreement with the report by ICRISAT, (2015) that drought, edaphic, diseases, and seed were the major challenges facing groundnut production in Nigeria. The pair-wise comparison results revealed that inadequate finance is the most limiting constraint to groundnut production in the study areas. This is corroborated by the economics principle that capital is the most important factor of production because all other factors can be acquired through it. Followed by inadequate finance is the drought. This is in tandem with ICRISAT, (2015) report that drought stress at the beginning and end of groundnut season affects plant establishment, poor yield, crop failure, pod formation, and risk of aflatoxin infection.

The majority of the respondents in the study area were not aware of groundnut haulm as a feed resource. This result agrees with Rehab*et al*. (2004) that reported a poor understanding of the nutritional and economic value of groundnut haulm in ruminant diets by livestock farmers in Egypt. As a result of low awareness of groundnut haulm as livestock feed, the majority of the groundnut farmers both Morro and Ogbomoso allowed the haulms to decay in the field as an organic manure for improvement of soil fertility and few of them allow it to be grazed alongside other weeds by cattle. This is in agreement with the finding of Sansoury and Emery (1982) that crop residues as livestock feed is faced with challenges of alternative uses like fuel,composting, construction and pharmaceuticals.

Study two

Chemical composition, pellet quality, and acceptability of urea treated or untreated groundnut haulms-based pelleted diets.

Chemical composition of groundnut haulms from different locations

The dry matter range of 92.91 - 93.08% in this study is in agreement with 93.73% reported by Abeer (2006) and 93.7% (Asaolu *et al*., 2010) but slightly higher than 91% obtained by Myer *et al*. (2010) for groundnut haulm. Leaf dry matter is used as an indicator of plant resource use in plant functional trait databases (Vaieretti *et al*., 2007). The higher crude protein of groundnut haulm from BDS than from OGB and AKY may be partially due to location effect, cultivar differences, cultural practices, and soil fertility as reflected in the crude protein of the groundnut haulm. There is a high correlation between the soil nutrients and the chemical composition of the crops. Yasar and Mehmet(2013) also reported differences in crude protein in groundnut haulm due to genotypic effects. Groundnut haulm from BDS had higher potential as a protein source to the animals as confirmed from higher crude protein content than from other sources.

The ash content ranged from 15.90 to 17.15%. This conflicts with 8.6% reported by Myer *et al.* (2010) and 18.0% by Abeer (2006). The ash content represents the inorganic matter and mainly the plant minerals. The values obtained in this study are optimum for the animal since it is compared favourably with the values reported by other authors as adequate for sheep.

The ether extracts ranged from 2.52 to 2.63%. Groundnut haulm, a crop residue, is low in oil content. The range obtained in the present study falls below 2.85% reported by Rahab *et al*. (2004) but higher than 1.16% by Abeer, (2006). The crude fibre for BDS was similar to OGB but lower than for AKY. This may be partially due to differences in cultivar or time of harvest because the older the plant the higher the fibre content.

The NFE for OGB was higher than both from BDS and AKY. This may be probably due to the cultivar effect which may result in a difference in the chemical composition of the groundnut haulms. The NFE is a rough estimate of the sugar and starch content of feedstuff, which can be easily digested by the rumen microbes as a source of energy and enhance their fibre degradation activities in the ruminants. The values recorded in this study 41% and 48% were lower than 44.52% and 52.4% reported by Rahab *et al*. (2004) and Abeer (2006), respectively.

The fibre fractions (NDF, ADF and ADL) are very important in ruminant feeding. The NDF or forage fibre amount or plant cell wall content determines intake and the digestibility of feed. The higher the NDF the lower the digestibility. The NDF observed ranged from 45.99-60.13% and lower than 38.1 and 31.8% by Desta and Gebru (2018) and Rehab *et al*. (2004) for groundnut haulms. The ADF consists mainly of lignin and cellulose. It engenders low digestibility of feed (Babayemi *et al*., 2004). The ADF obtained for the groundnut haulms from study locations ranged from 39.99 to 50.01% but lower than 20.12% for groundnut haulm reported by Rehab *et al*. (2004). The differences may be partially due to the age at harvest or the varietal effect. Lignin, according to Van Soest (1994) is generally believed to be a major component limiting the digestion of forages. The ADL value observed in this study ranged from 18.50-25.22% and was higher than 18.6% for groundnut haulms reported (Desta and Gebru, 2018).

Hemicellulose and cellulose are cell wall carbohydrates of tremendous importance in ruminant nutrition as the primary source of energy to the animal through the fermentation activities of the rumen microorganisms. Although, not digestible by monogastric animals but digestible in ruminant by rumen microbes in the process of fermentation. The cellulose obtained ranged from 21.49-24.79% and were similar in all the locations but higher than 11.75% reported by Rehab *et al*. (2004). Both hemicellulose and cellulose are fermented by rumen microbes to produce volatile fatty acids (acetate, propionate, and butyrate) which are the primary sources of energy to the ruminants. They are responsible for up to 70% of the energy for the ruminants (John, 2005).

Mineral composition of groundnut haulms from different locations

There were differences among the mineral composition of groundnut haulms from the studied locations. The mineral composition of a crop may be a reflection of the mineral or fertility condition of the soil in the respective locations. Ca, P, Na, and Zn followed the same pattern and was higher for groundnut haulm from BDS than for those from OGB and AKY. Mg and K were also higher from BDS and followed the same trend. AKY had the higher value for Fe. Higher values for all macro minerals especially P from BDS than from other studied locations may be partially responsible for higher groundnut yield from BDS than from OGB. Phosphorous has been reported to be the most required mineral by groundnut (ICRISAT, 2015).

Proximate composition of urea treated and ensiled groundnut haulm

The values dry matter of urea treated groundnut haulm compared to untreated obtained in this study were similar and optimum for the animals. The dry matter contains the organic and mineral portion of feed after the moisture has been removed. Urea treatment did not affect the dry matter of the groundnut haulm from this study.

Urea treatment and ensiling of crop residue or urea ammoniation have been established to enhance crude protein content and digestibility. Babayemi (2010) reported an increase in crude protein of urea-treated *Panicum maximum* and Adewumi *et al*. (2000) also reported an increase in digestibility of rice stover due to ammoniation. The increase in crude protein of urea-treated groundnut haulm observed in this study compared to untreated is consistent with the results of Olafadehan and Adebayo (2016) who reported an increase in crude protein content of urea-treated threshed sorghum top compared to untreated. The improvement in crude protein value observed in urea ammoniated groundnut haulm may be due to the conversion of urea to ammonia by urease enzymes secreted by the microbes which are natural inhabitants of groundnut haulm and serve as a source of ammonia nitrogen which increases the protein content of the haulm.

The lower value of crude fibre of urea treated groundnut haulm 21.20% compared to the untreated 25.04% may be as a result of removal of refractory phenol compounds (p-coumeric or ferrulic acid) of the cell wall by the ammonia. This result corroborates the report of findings of Olafadehan and Okoye (2017), who reported a reduction in crude fibre content of urea treated cowpea husk when compared to the untreated.

Chemical composition of experimental diets

The dry matter content of the diets which is left over after the moisture or water has been removed contains all the nutrients in the feedstuff. The higher the dry matter, the more the nutrient in the feed and the better for the animal. The dry matter of the diets ranged between 93.08 to 93.64% and was similar. The organic matter of a feed is obtained when the ash portion is removed from the dry matter. It consists of protein, carbohydrates, lipids, vitamins, and nucleic acids. The organic matter recorded for the diets in this study follows the same trend as the dry matter, they were high and similar among all the treatment groups. Urea treatment and pelleting at an individual level or when combined did not affect either dry or organic matter components of the diets under the present experimental condition.

The crude protein content of the diets ranged between 9.55 and 11.85% and was higher than the critical value of 7.0% for small ruminants according to NRC (1981) while it approximately falls within the minimum protein requirement of 10-12% recommended by ARC (1985) for ruminants.

The ash or content of the diets ranged between 11.45-12.75% and was not significantly different by urea treatment and pelleting. These values fall within 7.89-13.94% ash content in diets fed to WAD sheep by Amuda (2013) but higher than 4.6-6.56 of Olafadehan and Okoye (2017) who fed Red Sokoto goats with urea treated and ensiled cowpea husk based diets.

The ether extract content falls below 6-7% that may likely decrease microbial fibrolytic activity in the gastrointestinal tracts and resulted in reducing the digestibility of roughage-based feeds (Bauman *et al*., 2003).

The crude fibre ranged from 23.56-25.91% and was higher in pelleted diets than the unpelleted. This may be partially due to the higher amount of crude fibre from soluble proteins attached to the pelleted diets, which have more surface areas than the unpelleted. The crude fibre provides energy for the ruminants when the cellulose and hemicellulose are fermented by the rumen microorganisms.

The nitrogen-free extract for the urea treated and pelleted was the lowest probably because of the loss of sugars during urea ensiling and pelleting. The Nitrogen free extract of the diets ranged from 40.48-50.05% and was similar to 43.30-46.25% in diets fed to WAD sheep (Amuda, 2013).

The NDF is a measure of forage fibre or cell wall. The NDF of the diets was not affected by urea treatment and pelleting and ranged from 54.47 for D1 to 56.87 (D3). This value is below 55.0-60% that can limit forage intake and digestibility (Bamikole *et al*., 2004).

The acid detergent fibre (ADF) ranged from 39.87% for D1 to 42.58% in D2. This value was lower than 31.2-37.8% in diets fed to Red Sokoto goats (Olafadehan and Adebayo, 2016). The proportion of ADF in a diet determines intake and digestibility, the higher the value, the lesser the intake and digestibility due to the presence of lignin in ADF.

The acid detergent lignin (ADL) of the diets range from 19.30% for D1 to 21.10 in D2 but were all similar. Lignin is indigestible by the animals, the higher the value in a diet, the lower the digestibility. ADL was not affected by urea treatment and pelleting.

Cellulose and Hemicellulose are cell wall carbohydrates that are digestible by rumen microbes during fermentation that yielded volatile fatty acids used by the ruminants as sources of energy. The hemicellulose value observed in this study ranged from 13.16±2.00% in D4 to 14.60±2.06% for D1 but were all similar. The cellulose values were similar in D2, D3, and D4 but higher than D1. This may be partially due to reduction in lignin or separation of lignin and cellulose matrix through either pelleting or urea treatment thereby making more cellulose available in the processed diets.

Mineral composition of experimental diets

Minerals are inorganic nutrients required by animals for optimum performance. Those required in relatively large amounts in the diets are referred to as major or macro minerals while those elements or minerals needed in relatively small amounts are referred to as micro or trace minerals.

The calcium in the diets ranged from 0.26 in D1 to 0.29% in D3. This value falls within the required range of 0.20-0.82% for sheep (NAS, 1985). The phosphorus range from 0.34% in D1 to 0.36% in D3 and D4. It is within the optimum value of 0.16-0.38 for sheep. The Magnesium range is between 0.23-0.26% which is slightly higher than the required range of 0.12-0.18% for sheep but below the maximum tolerable level (NAS, 1985).

The potassium in the diets ranged from 0.59-0.69% and falls within the required range of 0.50-0.80% for sheep (NAS, 1985). The value for sodium ranges from 0.14% in D1 to 0.19% in D3. The values for D1, D2, and D4 were within the required range of 0.09-0.18% but the 0.19% value for D3 is slightly higher but within the tolerable level.

The manganese range from 37.30 g/kg in D4 to 42.30 mg/kg in D4 to 42.30mg/kg for D2. The requirement range of manganese for sheep is 20-40 mg/kg. From this study, only D2 has slightly exceededthe requirement range but is far lower than the 1000 mg/kg maximum tolerable level (NAS, 1985).

The zinc value ranged from 25.80 mg/kg in D4 to 33.40 mg/kg in D1. This range falls within the 20-33 mg/kg requirement for sheep (NAS, 1985). The mineral components of the diets in this study are adequate for the optimum performance of sheep. Deficiency of minerals causes deficiency symptoms while excess can lead to toxicity in animals.

Pellet quality of diets

Pelleting, a form of physical treatment, crushes cell walls thereby increasing particles' surface area for microbial attachment and hence improved their activities. Pelleting also alleviates storage as well as shrink loss issues associated with roughage handling and processing. It allows for ease of transportation from one place to another due to its increased buck density thereby reducing both transportation cost and stress.

Pellet durability index (PDI) and hardness are one of the major properties used in assessing pellet quality. The higher the PDI value the better the quality since the pellet with the higher value will be able to resist handling, transportation, and direct force without crumbling.

The higher hardness of urea treatment and pelleted groundnut haulm based diets of 207.58N compared to 146.28N in untreated may be due to reduced particle size as a result of reduction of fibre content or breaking of lignin matrix by urea which enhances higher gelatinization and stronger cohesion of particles in urea treated pelleted groundnut haulm based diets compared to the untreated.

Feed acceptability

One of the direct and quickest methods employed in assessing the nutritive value of a feedstuff is acceptability or free choice intake done using cafeteria techniques as described by (Bamikole *et al*., 2004; Babayemi *et al*., 2006). It is an *in vivo* study that shows the attitude of animals to a feedstuff with regards to acceptance or refusal. From the results obtained in this study, the animal showed the highest preference for feeds that were not treated with urea nor in pellet form. This may be attributed to the lack of repulsive odour of ammonia in urea treated and seemingly hardness of the pellets compared to diets that were treated with urea and presented in pellet form. Pelleted diets that were not treated with urea had the second coefficient of preference followed by urea treated- pelleted diets and least in urea treated unpelleted. It was observed that the likely reason for the refusal was the traces of pungent odour of ammonia from urea. From the study, pelleting increases feed acceptability as indicated by higher value for untreated pelleted diets than the treated pelleted. The results from this study aligned with that of Owen (1994) that the extent to which the intake responds to the amount of feed offered to small ruminants is modified by physical forms and chemical processes. Generally, acceptability, availability, season, and health statutes of the animal affect feed intake by an animal.

Study three: *In vivo* gas production, rumen fermentation characteristics, and microbial population of groundnut haulm and experimental diets

One of the most commonly adopted techniques used in the assessment of nutritive value of a feedstuff is *in vitro*fermentation and gas production (Menkel and Steingass 1988). Gas production is the result of the fermentation of carbohydrates to acetate, propionate, and butyrate with little gas from protein as compared to carbohydrates fermentation (Makkar *et al*., 1995).

The variables used in describing fermentation characteristics are gas production from the soluble fraction (a), the gas production from the insoluble but degradable fraction (b), potential extent of gas production fraction (a+b), gas production rate content (c), incubation time (t) and gas volume production (Y) at a time (t).

***In vitro* gas production of urea treated and untreated groundnut haulms from different locations**

From this study, there was no observable gas production from soluble fraction 'a' for either of the treatments possibly because the soluble fractions did not contain enough fermentable carbohydrates that could produce a detectable amount of gas since gas production from the substrate is known to come only from fermentable carbohydrates. It may also be that the major volatile fatty acid that is produced is propionate which production is associated with a small quantity of gas from buffering of the acid.

The observed gas produced from insoluble but degradable fraction for urea treated groundnut haulm (10.57 ml) was higher than the untreated (2.0 ml) may be as a result of the addition of NH_3-N to the treated haulm in the presence of fermentable carbohydrate which increased microbes activity for higher gas production or reduction in fibre content which increase the cell wall carbohydrate accessibility to the microbes and thus higher degradation and gas production.

The higher gas production (a+b) follows the same trend as (b) since there were no observed values of gas production for a soluble fraction (a). The gas production or digestion rate (c) was similar among all the treatments. The gas production from b and rate of gas production is known to be very important indices in evaluating the nutritive value of a diet.

The lowest incubation time t, (15 hrs) recorded for urea treated groundnut haulm than 19hr recorded for untreated could be attributed to increased activity of the degradation microbes and reduced fibre component of urea treated groundnut haulm according to Olafadehan and Adebayo (2016) who reported reduced fibre fraction in threshed sorghum top as a result of urea ammoniation. The peak gas production Y at time t follows the same trend.

Dry matter degradability of urea treated and untreated groundnut haulms

Higher dry matter degradability of urea-treated groundnut haulm was higher than untreated groundnut haulm this may be partially adduced to the potential of ammonia emitted that breaks the lignocellulosic bond, thereby increasing the microbial degradation by microbes. Alkaline treatment, according to Fahey *et al*. (1993), disrupts the lignin-hemicellulose matrix in all cell walls of forage. It may be also due to higher NH_3 in the rumen that reduces the activity of the methanogens.

***In vitro* fermentation parameters of urea treated and untreated groundnut haulms at 24 hrs incubation period**

Gas production during *in vitro* fermentation though a nutrient waste but useful in evaluation of nutritive quality of a feed (Mauricio *et al*., 1999).

From this study, D4 which was treated and pelleted GH had numerical higher values of ME, OMD, and SCFA but the increases were not enough to elicit significant difference for these parameters compared to the untreated diets. Gas production has a direct relationship with SCFA (Beuvink and Spoelstra, 1992), higher gas production is an indication of a higher SCFA. Menkel *et al*. (1979) reported that SCFA is directly proportional to metabolisable energy. From this study, the higher numerical value for organic matter digestibility and/or gas production in urea treated groundnut haulm was not sufficient to translate into a higher significantly statistical value in SCFA. Metabolisable energy followed the same pattern. The study reveals that urea treatment and pelleting tended to increase the energy value of feed. It was reported by Wittenberg and Boadi (2001) that fermentation of high fibre forages by the microorganisms in the forestomach of ruminants leads to loss of gross energy in the diets up to 4-12% as methane.

Methane production of urea treated and untreated groundnut haulms at 24 hours incubation

The lower value of methane observed for urea treated groundnut haulm could be attributed to reduced activities of methanogens due to the presence of higher ammonia because of urea treatment or the treatment may serve as a sink for hydrogen in GIT, thereby reducing methanogenesis occasioned by a combination of H_2 and CO_2 production during rumen fermentation. Hulshof *et al*. (2012) reported that supplementing nitrite (NO_3) with high fibre diets for ruminants can help to trap hydrogen ions, therefore hindering methane production.

***In vitro* fermentation characteristics of groundnut haulms from different locations at 24 hours incubation period**

The gas production from soluble fractions (a) of GH was not detectable for all the groundnut haulms from different locations in this study. The values for insoluble but degradable (b) and potential degradability (a+b) were higher for OGB than BDS and AKY in this study. The rate of gas production (c) and gas volume were similar in the studied locations. The incubation time 't' was higher for BDS and AKY than OGB. The gas volume was similar for all the locations. These results may be attributed to the soil, environmental, or cultivar effects on the chemical composition of the GH from different locations.

***In vitro* fermentation characteristics of urea treated and pelleted groundnut haulm based diets at 24 hours incubation period**

The gas produced from the soluble fractions 'a' in the diets was not detectable in this study. The gas production from b and rate of gas production is known to be very important indices in evaluating the nutritive value of a diet. In the present study, urea treatment and pelleting had no effect on the two parameters but the higher numerical value for pelleted and urea treated diet (D4) may be attributed to smaller particle size due to pelleting and reduced fibre components as a result of ammoniation. Pelleted diet (D3) also recorded the numerical fastest digestion rate ‘c’, possibly as a result of larger surface area for microbial attachment and degradation of the substrate. The gas production from insoluble but degradable fraction ‘b’ and potential extent of gas production ‘a+b' were highest in urea treated pelleted diet (D4). This could be attributed to the large surface area for microbial attachment as a result of pelleting and availability of non-protein nitrogen (NPN) from urea treatment that resulted in higher microbial activities. Bryant (1973) reported that cellulose-degrading bacteria requires a certain amount of nitrogen from NPN source for optimal growth while Russell *et al*. (1990) added that cellulolytic bacteria lack effective means to transfer nitrogen from amino acid origin across their plasma membrane into the cytoplasm. The similarities between the gas production rate constant 'c', incubation time‘t' and gas volume 'Y' may be due to the homogenous nature of the gross composition of the diets.

The *in vitro* fermentation parameters metabolisable energy (ME) short-chain fatty acids, Organic Matter Digestibility (OMD), and methane gas for all the diets were similar. The slightly higher numerical value observed in urea treated and pelleted diets (D4) for ME and OMD may be attributed to higher surface area for microbial attachment and more ruminal NH_3-N production which increase activities of rumen microbes, thus higher fibre digestibility and/or more energy availability.

Microbial fermentation characteristics of urea treated and pelleted groundnut haulm based diets in WAD rams

The ruminal pH value or range is very important for the optimal performance of rumen microbes. It determines the dominant species of microbial population in the ruminant stomach and the intestines. The ruminant pH range of 6.50—6.65 obtained in this study is in agreement with 6.0—7.0 considered as optimal for ruminal microbes activity (John, 2005). Lack of effect of treatment on pH may be due to relative similar value of NDF the content of the diets which possibly put the chewing time and salivation rate at the same level for all the treatment diets.

Pelleting is a particle size decreasing process that increases the surface area for microbial attack and thus increases their activities. From this study, pelleting increased the production of total volatile fatty acids (VFA), ammonia nitrogen (NH_3-N), and microbial populations. This may be attributed to increased fibre degradation or carbohydrate fermentation which translated into higher total VFA or energy production. The higher value of NH_3-N for pelleted diets could be as a result of faster proteolysis of dietary protein and non-protein nitrogen (urea) compared to unpelleted diets

Higher total Volatile Fatty Acid (VFA) obtained in the current study for urea treated diets over untreated may be due to reduction in fibre content that translates into increased structured carbohydrates degradation and thus higher total VFA production by the rumen microbes. This is in agreement with Paterson *et al*. (1981) who reported a 14% increase in NDF digestibility due to ammoniation.

The NH_3-N values for urea-treated diets, as expected, are higher than in untreated. This may be likely due to microbial degradation of urea that resulted in NH_3-N production. Ammonia nitrogen is known to be preferred by cellulolytic bacteria (Bryant, 1973) due to inefficient means of transmission of nitrogen derived from amino acids across theirplasmalemma(Russell *et al*., 1996). The NH_3-N ranged of 24.96-29.19 mg/dl observed in this study is slightly higher than 5-25mg/dl reported by Preston and Leng (1987) as optimal level in rumen liquor for microbial growth. This may have partially resulted from pelleting and urea treatment which increased microbial proteolytic activities and thus available NH_3-N in the rumen.

Volatile fatty acids (VFA) are the most important end products of carbohydrate breakdown by microbes in the rumen and account for about 70% of energy for ruminants (John, 2005).

The higher microbial population of bacteria, protozoa, and fungi in the current for pelleted diets suggests faster accessibility of the microbes to dietary nutrients for multiplication and growth in compassion to un-pelleted diets. The result is in agreement with the result of Peterson (2014) who reported higher surface area for the microbial attack in pelleted diets than in unpelleted. Urea ammoniation is known to increase fibre digestibility and supplies rumen microbes with NH_3-N for growth or multiplication and is therefore regarded to possess a combination of treatment together with nutrient supplementation advantages (Cloete and Kritzler, 1984).

The ratio of the VFA fractions is very important because it reflects the glucogenic (glucose) and lactogenic (fat) substrate availability and metabolism efficiency in ruminants. Acetate is a lactogenic (fat) substrate and linked to high fibrous sources which play vital roles in milk fat. High fibrous to low energy feeds results in high acetate: propionate production. Propionate is glucogenic (glucose) and is traced to readily fermentable carbohydrate sources which is an indication of the high prospect of energy availability for weight gain and milk glucose, an advantage for a lactating animal for milk yield. Butyrate is important in the production of ketone bodies which serves as an alternative source of energy for the synthesis of fatty acid and body tissues. It is used as an alternative source of energy when the dietary energy is low.

Balanced ratio of acetate: propionate is needed for nicotinamide adenine dinucleotide phosphate (NADPH) supply from propionate which is needed for the conversion of excess fat from acetate in the adipose and regeneration of oxaloacetate for effective VFA energy metabolism in the tissue otherwise it will lead to heat increment in animal (Egan, 1977; Crongel *et al*., 1987; Crangel *et al*., 1991).

The molar ratio of 41:31:27 for acetate, propionate, and burytrate, respectively observed in the present study is in contrast to 65:25:10 reported by Inyang (2017) for roughage based diets. This could be due to the high proportion of fermentable carbohydrates in the diet. The diets may have less problem of heat increment and probably be more suitable for meat-producing stock vis a vis dairy animals. Pelleting had a higher ratio of acetate: propionate than the unpelleted probably because of faster utilisation of large surface area of pelleted diets by lactate producing microbes compared to those involved in the production of propionate and butyrate. Pelleting had a higher bacteria, protozoa, and fungi population than diets that were not pelleted. This may be attributed to rapid microbial attack and increase microbial activities, growth, and multiplication due to large surface areas consequent upon pelleting, a particle size reducing process. Also, higher fungi and protozoa count for urea treated diets than untreated may be as a result of additional supply of nitrogen (NPN) through urea treatment for increasing microbial activities. Bacteria count was not affected by urea treatment probably the amount of nitrogen supplied from urea was not sufficient to produce a detectable difference between the urea treated and untreated.

Urea treatment x pelleting had an effect ($P<0.05$) on volatile fatty acid (TVA) and propionate production. Untreated pelleted (D3) had the highest values of VFA and propionate. Urea treatment resulted in a 1% decrease in TVA production in rams allotted pelleted diets but resulted in a 3.4% increase in those fed unpelleted diets. This may be due to the NH_3-N range of (24.42—25.50 mg/dl) which is within the considered optimal range for microbial growth obtained in non-pelleted diets compared to (28.68—29.69 mg/dl) in pelleted diets which may be higher for normal microbial activities thus lower VFA production. According to Preston and Leng (1987), the optimal level of NH_3-N for microbial growth is 5-25 mg/dl. The synergy of urea and pelleting may favour the production of propionate production which may be the reason its higher value in urea treated pelleted value than untreated unpelleted.

Study four: Growth performance of WAD rams fed urea treated and pelleted groundnut haulm based diets

Growth Performance of WAD rams fed urea treated and pelleted groundnut haulm based diets revealed that Dry matter intake (DMI), Daily weight Gain (DWG), and Feed Conversion Ratio (FCR) were affected by pelleting. The higher DMI of animals fed pelleted diets than animals on non-pelleted diets may be as a result of faster passage rate of pelleted diet in GIT as a result of reduced particle size. Higher DMI with pelleted diets has been reported by several authors, with increases ranging from 15 to 26% in comparison with non-pelleted diets (Beardsley, 1964; Bonfante *et al*., 2016; Campling and Freer, 1966). The improved DMI observed in pelleted diets was translated into increased weight gain (WG) as indicated by higher weight gain in pelleted feed than unpelleted. This result conflicts with Bonfante *et al*. (2016) who reported similar WG for heifers on pelleted and unpelleted diets. However, this result agrees with Beardsley (1964) that reported increased daily gain with pelleted rations.
The FCR follows the same trend as the weight gain. The FCR is a measure of the ability of an animal to convert feed into bodyweight. The lower FCR of animals on pelleted rations is an indication of better feed utilisation efficiency. This may be due to the prevention of ingredient sorting by the animals and increased nutrient availability and efficiency of utilisation.

The higher microbial protein synthesis in pelleted diets than in the unpelleted can be attributed to higher feed intake of pelleted diets. This result corroborates the reports of Fernando *et al.* (2010) that increased feed intake enhanced microbial protein synthesis. Microbial protein synthesis for rams on urea treated diet was similar to those fed untreated diets. This may be due to the lack of adequate energy to translate the extra nitrogen into protein by the microbes. The result obtained in this study contradicts Olafadehan and Adebayo (2016) that reported higher microbial protein yield in Red Sokoto goats fed ammoniated sorghum top compared to unammoniated.

Urea ammoniation has both treatment and supplementary advantages by improving digestibility and also serving as a source of NH_3-N to rumen microbes. In this study, animals on urea-treated diets had higher DMI, DWG, and also better FCR. This may be adduced to a reduction in fibre content due to urea treatment and increased NH_3-N supply that possibly resulted in better feed utilisation. This result agrees with Olafadehan and Adebayo (2016) which reported increased performance of Red Sokoto goat fed urea treated threshed sorghum tops.

The combined effect of pelleting and urea treatment resulted in lower FCR or better efficiency of feed utilisation. The higher feed efficiency of utilisation observed may be due to the synergistic effect of the increased dry matter intake, due to pelleting and higher, digestion with additional NPN supply resulting from urea ammoniation.

The cost-benefit of feeding urea treated and pelleted groundnut haulm based diets to WAD rams

The cost-benefit analysis in this study reveals that rams on pelleted diets incurred higher feed cost (FC) and total feed cost (TFC) than those fed unpelleted diets. This may be partially due to the high cost of pelleting production and also higher feed intake by animals on pelleted diets than those fed unpelleted. The greater weight gain by the animals on pelleted diets resulted in higher monetary benefits than those on unpelleted diets. This result was in consonant with the report of Obasa *et al*. (2017) that pelleted feed increased the profit margin in broiler chicken. On the contrary, urea treatment did not affect the monetary gain of the animals. This may be as a result of marginal higher weight gain by the animals on urea treated diets than those fed the untreated which could not translates to higher net benefit (NB) in the animals fed treated diets than the untreated. This may be due to the higher total cost of production of urea-treated diets for animals fed the treated diets. Labour and water availability were among the factors identified to affect the economy of urea ammoniation, especially where family labour and water are not easily available (ESGP, 2007). The combined effect of urea treatment and pelleting had a higher net benefit (NB). This may be associated with higher feed intake and efficiency of utilisation of pelleted urea-treated feeds that translated into higher weight gain and eventually better monetary return.

Digestibility of urea treated and pelleted groundnut haulm based diets by WAD rams

Pelleting, a size-reducing process is expected to increase digestibility due to the large surface area for microbial and enzymatic attacks. On the contrary, due to faster digesta clearance in the GTT, the digestibility of pelleted diets may be low in certain cases. In the present study, pelleting reduced ($P<0.05$) digestibility of dry matter (DM), acid detergent fibre (ADF), crude protein (CP), and acid detergent lignin (ADL) compared to un-pelleted. These results agree with Campling and Freer (1966) who reported low digestibility of dry matter when pelleted forges are compared to un-pelleted. Also, Greenhalgh and Reid (1973) observed a 10% reduction in digestibility of dry matter of pelleted forages in sheep in comparison with long stem form. Reduction in digestibility due to pelleting may be as a result of decreased ruminal retention time occasioned by an increased rate of passage which enables the substrates to escape microbial breakdown. However, at a 5% confidence limit, organic matter (OM), ether extract (EE), crude fibre (CF), neutral detergent fibre (NDF) hemicellulose, and cellulose had similar digestibility. This may be partially due to the optimum retention time of both pelleted and pelleted diets in the rumen and other parts of GIT for the microbial breakdown of the nutrients. The longer the retention time of chaffed roughages in the rumen, the higher the digestibility (Pearce and Moir, 1964).

Urea treatment enhanced digestibility by reducing fibre content with the additional advantage of the supply of NH_3-N for increased microbial population and activities. In the current study, urea treated diets had similar values of digestibility for dry matter (DM), the crude protein (CP), crude fibre (CF), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), hemicellulose and cellulose. This may be partially due to an insufficient amount of ammonia from urea breakdown to improve the microbial protein supply and activities. This result contradicts Morris and Mowat (1980) who reported a 9% and 14% increase in DM, OMN, NDF, digestibility of ground, and/or ammoniated corn stover on yearling steers, respectively due to urea treatment.

From the current study, the interaction of urea treatment and pelleting affected the digestibility of ADL, NFE, and ether extract digestibility. Rams on D3 had the highest digestibility values for ether extract (EE), nitrogen-free extract (NFE) while acid detergent fibre (ADL) was highest in D1. Urea treatment x pelleting was similar for dry matter (DM), organic matter (OM), crude protein (CP), crude fibre (CF), neutral detergent fibre (NDF), acid detergent fibre (ADF), hemicellulose, and cellulose.

Nitrogen utilisation in WAD rams fed urea treated and pelleted groundnut haulm based diets

Nitrogen is needed by rumen microbes for their protein synthesis. Nitrogen is made available to the microbes through dietary protein or non-protein nitrogen (NPN). An adequate supply of nitrogen to rumen microbes improves their activities in carbohydrate breakdown or fermentation to volatile fatty acids or energy sources for ruminants. It is also important for microbial cell protein synthesis. Undegradable protein in the rumen or small intestine and part of excess ammonia that is deaminated in the liver to urea is excreted in the faeces or urine respectively.

From this study, pelleting affected nitrogen utilisation. Pelleted diets had higher values for nitrogen excreted in the faeces and urine than in the unpelleted. This observation may be due partly to faster and increase proteolytic activities of the rumen microbes that resulted in higher NH_3 production than could be fixed by the microbes and thereby excreted in the urine as urea. Also, faster digesta clearance may result in a high amount of undegradable or by-pass protein leaving the stomach for the intestine at the rate the proteolytic enzymes could not handle, thus resulting in increased nitrogen excretion in the faeces. Van Soest (1982) reported that nitrogen excreted in faeces is from dietary sources and that in urine is mainly from defaunated microbes that were not utilised by the animals and from excess NH_3 converted to urea. The 74% nitrogen retention for pelleted diets in this study was high though lower than for the unpelleted which is an indication that pelleting had no negative effect on nitrogen utilisation by the animals.

Microbial protein synthesis is very vital in ruminant nutrition since the rumen microbes are the main contributors of protein to the ruminants (Hristov and Broderick, 1996). From the current study, MPS for pelleted diet was higher (5.81g/day) than for those on unpelleted (5.17g/day), this might be partially attributed to the higher feed intake of pelleted diets than the unpelleted. Fernando *et al.* (2010) reported that feed intake is one of the main factors influencing microbial protein synthesis. It may also be adduced to the low retention time of the digesta in the rumen for the adequate microbial breakdown of the dietary protein for their protein synthesis. Microbial protein that enters the small intestine contributes the major source of fermentable amino acid to the host animals which is an indication that pelleting improve the nutritive value of a diet.

The study revealed that urea treatment had similar values for nitrogen balance and retention for urea-treated and untreated diets. The value for nitrogen retention indicated a sufficient amount of nitrogen for optimal performance of the microbes and the host animals. It was expected that ammoniation of diets should result in higher microbial protein value due to presumed higher degradable protein from NPN but not observed in the present study. This may be due to insufficient fermentable energy to translate the non-protein nitrogen from ammoniated diets to protein by the microbes (Olafadehan and Adebayo, 2016). Another reason may be attributed to a lack of other factors like dietary carbohydrates, ruminal pH, feed intake, and dietary fats at optimal levels.

There was no interaction or combined effects of urea treatment and pelleting for Nitrogen utilisation and microbial protein synthesis in the present study.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY

Livestock production in Nigeria as obtained in any other developing country of the world is hindered by feed shortage. As a result, crop residue like groundnut haulm profers a potential alternative as a livestock feed. However, groundnut haulm for livestock is faced with challenges such as low awareness of its feeding value among groundnut farmers leading to its wastage in the field (low returns from groundnut production), high transportation cost due to bulkiness, low digestibility (high fibre content) and protein loss to rumen microbes. Pelleting and urea treatment have been widely used to improve the nutritive value of bulky fibrous roughages for ruminants but information on feeding urea treated pelleted groundnut haulm based diets is scanty in Nigeria. Therefore, the nutritive value of urea treated and pelleted groundnut haulm-based diets for WAD rams was investigated.

Study one assessed the production of groundnut and awareness of groundnut haulm as a feedstuff by farmers in groundnut producing areas of Morro LGA and Ogbomoso LGAs of Kwara and Oyo States, respectively. Necessary information regarding groundnut production and haulms use was collected using focus group discussion and individually structured questionnaire, and results analysed using descriptive statistics (SPSS, 2000).

Groundnut productivity was higher in Morro LGAs of Kwara State than in Ogbomoso areas of Oyo State, with 66% of the farmers from Morro realising more than two tonnes of groundnut per hectare compared to only 20% for Ogbomosho and the haulm estimated yield range of 2 to 4 tonnes/hectare estimated from groundnut yield of 1-2 tonnes/ha from the studied locations.

The most limiting constraint affecting groundnut production from the two locations as suggested by the farmers was inadequate to finance and they suggested government intervention through Agricultural loans from banks with bearable interest rates. Most of the groundnut farmers in the study areas (98%) in Morro and (100%) in Ogbomoso were not aware that groundnut haulms are used or sold as livestock feed, therefore, they were abandoned in the fields to decay for soil fertility improvement.

Groundnut haulm from Bode Saadu (Morro LGA, Kwara State) was higher in values of DM, CP and minerals (macro and micro) than those from Ogbomoso.

Study two examined the chemical composition, pellet quality, and acceptability of urea-treated groundnut haulm-based pelleted diets.

Groundnut haulm collected from the study locations were treated with urea and ammoniated using standard procedures. The haulms were mixed with other supplements to formulate different rations. The chemical composition of the haulms and feeds was determined by the procedure of AOAC (2002). The pellet hardness and durability index were measured by pellet tester and friability apparatus. The cafeteria technique was used to evaluate feed acceptability. Data collected was analysed using AVOVA and means separated by DMRT.

Urea treated (ammoniated and ensiled) groundnut haulms had higher crude protein but lower crude fibre values than untreated haulms. Pelleting and urea treatment did not affect dry matter, neutral detergent fibre (NDF) and ash content of experimental diets. Urea treatment of groundnut haulms elicited higher values of pellet durability index (PDI) and hardness. Urea treated-unpelleted feed was least preferred by the animals.

Study three investigated i*n vitro* gas production characteristics of urea treated groundnut haulm-based pelleted diets. The *in vitro* gas method, SCFA determination, and microbial population were based on standard procedures. Data were analysed using ANOVA (SAS, 2003) and means separated was by DMRT and significance declared at 5%.

Ammoniated and ensiled groundnut haulms resulted in higher *in vitro* dry matter degradability (DMD than unammoniated unensiled groundnut haulms but similar for metabolisable energy (ME), short-chain fatty acids (SCFA), and Organic Matter Digestibility (OMD). Methane production was lower in urea treated groundnut haulm when compared to untreated. Pelleting or urea treatment did not affect *in vitro* fermentation characteristics: ME, OMD, and SCFA of the diets

Urea ammoniation and pelleting of diets did not affect rumen pHin experimental rams.

Pelleting and urea treatment separately increased total volatile fatty acids (VFA) and NH_3-N as well as the microbial population in WAD rams. Interaction of pelleting and urea treatment had significantly higher total VFA production in WAD rams.

Study four assessed rumen fermentation characteristics, growth performance, nutrient digestibility, microbial protein yield, cost-benefit and nitrogen balance in WAD rams fed urea treated groundnut haulm-based pelleted diets.

The feeding trial was conducted in a 2 x 2 factorial arrangement in a completely randomised design for 105 days in an individual cage with provisions of feed and water *ad lib* followed by a digestibility study in metabolism cages. Microbial protein synthesis and cost-benefit were estimated using standard procedures. Data were analysed using ANOVA (SAS, 2003) and significance was declared at a 5% confidence limit.

Though dry matter intake (DMI) was similar between the treatments, pelleted diets improved weight gain and feed utilisation. Pelleting of high fibrous forage for ruminants increased production cost and resulted in marginal economic benefit.

Urea treatment alone improved efficiency of feed utilisation in WAD rams and combined effects of pelleting and urea treatment resulted in better feed utilisation or lower values of feed conversation ratio (FCR) in WAD rams.

Urea ammoniation had no significant effect but higher numerical values of dry matter and NDF digestibilities in WAD rams. Pelleting of feed resulted in higher numerical values of intake but lower digestibilities of Organic Matter (OM) and NDF in WAD rams.

Pelleting and urea ammoniation individually elicited positive nitrogen balance or enhance nitrogen utilisation in WAD rams.

Microbial protein synthesis is improved by pellet feeds probably due to increased feed intake occasioned by reduced particle size.

6.2 Conclusions

It can be established based on higher crude protein observed from groundnut haulm from Bode Saadu in Morro Local Government Area of Kwara State that location affected the chemical composition of groundnut haulm.

Also, the study revealed that the farmers in the study locations had optimal groundnut and haulm yields but were not aware of the importance of haulms as livestock feeds thus, they burn or abandoned them in the field.

Urea treatment of groundnut haulm and pelleting improved nutritive value of diets as reflected in better rumen fermentation, dry matter intake, and growth performance. Therefore, pelleted diets containing 40% urea treated groundnut haulm and concentrate supplement were adequate for WAD rams under the present experimental conditions.

In conclusion, West African Dwarf rams could be successfully and solely managed on urea treated pelleted feed mixture under an intensive system in the tropics based on the current experimental condition.

6.3 Recommendations

1. Groundnut farmers in Kwara and the Oyo States need financial support from the government and sensitisation campaign on awareness of groundnut haulm as livestock feed, which can also serve as an additional source of income for them and ultimately boost groundnut production in the States.
2. The two study locations are recommended as sources of groundnut haulm for small ruminant holders in Kwara and Oyo States, and environments.
3. Further research on the cost-benefit of urea treatment and pelleting of feed on a larger scale is needed for a better evaluation of the profitability of processed feed in sheep feeding.
4. More studies are needed with different combinations of urea treatment groundnut haulm and supplement mixture to determine the best ratio in the total mixed ration (TMR) or pellet feeds for sheep.
5. An intensive system of sheep management using complete feed like pellet should be promoted as this could go a long way of encouraging commercial sheep production in the urban areas, in reducing crop damage especially in raining season, and mitigating conflicts between livestock and crop farmers due to extensive systems of livestock production in the rural setting.

6.4 Contributions to Knowledge

1. Interaction of Urea treatment and pelleting on groundnut haulm-based diets improved its nutritive value for West African Dwarf rams.
2. Pelleted, urea-treated groundnut haulm-based diets enhanced the growth performance of West African dwarf rams.
3. West African Dwarf ram can survive under an intensive system of management in the rain forest zone of Nigeria by feeding exclusively on pelleted urea-treated groundnut haulm-based diets.

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APPENDIX 1- Questionnaire

Department of Animal Science, University of Ibadan, Nigeria.

Questionnaire on assessment of groundnut production and haulm use in Morro and Ogbomoso local government areas of Kwara and Oyo states of Nigeria, respectively.

Please note: All information provided on this form is intended only for research and will be handled with confidence, accept my appreciation.

SECTION A: SOCIO-ECONOMIC CHARACTERISTICS OF RESPONDENTS

a) **How old are you ?<20 ( ), 20 – 40 ( ) , 41-60 ( ), > 60 ( )**
b) **Sex**: Female ( ), Male ( )
c) **Religion:** Islam ( ), Christianity ( ), Others ( )
d) **Marital status**: Married ( ), Single ( ), Widow/er ( ), others (specify):

e) **What is your household size?**

f) E**ducation?** a) Non-formal ( ), b) Primary ( ), c) Secondary ( ),
d) Tertiary ( ), e) Arabic studies ( ) others (specify): \

g) **Profession?** a) Civil service ( ) , b) Farming ( ), c) Trading ( ),
(d) Pensioner ( ), e) Artisans ( ), f) student ( ), g) others ( )

h) **Other source of income** (means of livelihood):

i) **Land holding category**: a) landless ( ) b) small ( ), c) medium ( ) d) large

j) **GPS Coordinate**: latitude ( ) Longitude ( )

k) **Village/location**:

l) **Personal land size?** ………………. Acres | Hectares | Local Units (circle one)

m) **Cultivated land size?**Acres | Hectares | Local Units (circle one)

n) ***If local units, name of local unit****: 1 hectare = 7500 heaps (Local units)*

o) **Name of cooperative you belonged**

SECTION B CROPS GROWN AND THEIR RESIDUES UTILISATION

Cultivation Area & Yield (if using local units, specify below)				**Residue Use (if any allocated to 'other', specify below)**				
Crop	**Area Ha**	**Yield /tonne**		**Livestock Feeding**	**Burnt**	**Mulching**	**Sold**	**Other ***
		crop	**residue**					

Name of local unit (Area): 1 hectare = ………….7, 500 heaps (Local units)

Constraint(s) in groundnut / haulms production

Problem	Solution

Sources of manual labour

Major source of Labour	Family	Hired	Communal	Others(specify)
Tick one				

Sources of fund to the farmers:

Major Source of fund	Personal saving	Friends	Relative	cooperative	Agric bank loan	Commercial bank loan
Tick one						

FOCUS GROUP DISCUSSION

SECTION A

GENERAL INFORMATION

Name of Site/Village/LGA:

LGA: **Country:**

Number of Households in the Area:

GPS Coordinates of Meeting Location: **Latitude:** **Longitude:**

Number of Participants Present: **Males:** **Females:**

Date:

Start Time: **Finishing time:**

SECTION B

PROBLEMS, WITHIN GROUNDNUT PRODUCTION SYSTEM

	PROBLEM	SOLUTION(S)
1		
2		
3		
4		
5		

SECTION C

Rank problems based on number of times they were selected as more important in the pairwise comparisons (highest # = most important)

Problem	# of Times Chosen as More Important	Ranking (1 = most, 5= least)
1		
2		
3		
4		
5		

SECTION D

Complete pair-wise comparisons for the problems in the table below. For each comparison, record which problem is identified as the more important of the two.

PAIR	**PROBLEM CONSIDERED MORE IMPORTANT**
Problem 1 vs. Problem 2	
Problem 1 vs. Problem 3	
Problem 1 vs. Problem 4	
Problem 1 vs. Problem 5	
Problem 2 vs. Problem 3	
Problem 2 vs. Problem 4	
Problem 2 vs. Problem 5	
Problem 3 vs. Problem 4	
Problem 3 vs. Problem 5	
Problem 4 vs. Problem 5	

APPENDIX 2

Plate one: Collections of groundnut haulms in the field

Source: Field survey, 2017

APPENDIX 3

Plate two: Fresh groundnut (*Arachis hypogaea* L.) haulm

APPENDIX 4

Plate three: Compacting the urea treated haulm during ensiling

Source: Field survey, 2018

APPENDIX 5

Plate four: Observing the experimental animals

Source: Field survey, 2018

APPENDIX 6

Plate five: Groundnut haulm based pellets

Source: Field survey, 2018

APPENDIX 7

Plate six: An experimental animal feeding on pellets diet

Source: Field survey, 2018

APPENDIX 8

Plate seven: Pellet Hardness Tester Model EH 01

Courtesy: Pharmacaeutics and Industrial Pharmacy Laboratory, University of Ibadan

APPENDIX 9

Plate eight: DBK friability test apparatus

Courtesy: Pharmacaeutics and Industrial Pharmacy Laboratory, University of Ibadan

APPENDIX 10

Plate nine: Transportation of dry bulky groundnut haulm, Niamey

Courtesy: ICRISAT, 2015