ESTIMATING PERFORMANCE AND METHANE EMISSION FROM YANKASA LAMB RAMS FED DIETS CONTAINING VARYING LEVELS OF CAMEL'S FOOT (*Piliostigma thonningii)* LEAF AND POD MEALS

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JULY, 2018

DECLARATION

I declare that this dissertation titled "**Estimating Performance and Methane Emission From Yankasa Lamb Rams Fed Diets Containing Varying Levels of Camel's Foot (*Piliostigma thonningii)* Leaf and Pod Meals"** has been written by me in the Department of Animal Science, Ahmadu Bello University, Zaria, under the supervision of Dr. M.R. Hassan and Dr. S.B. Abdu. The information derived from the literature has been duly acknowledged in the text and the list of references provided. No part of this thesis was previously presented for another degree or diploma at any University.

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CERTIFICATION

This dissertation entitled "**Estimating Performance and Methane Emission from Yankasa Lamb Rams Fed Diets Containing Varying Levels of Camel's Foot (*Piliostigma thonningii)* Leaf and Pod Meals"** by **LAWAL Adetoun Muibat** meets the regulation governing the award of the degree of Master of Science in Animal Science of Ahmadu Bello University, Zaria, Nigeria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to Almighty Allah, the benevolent in mercy whom none has the right to be worshipped but HIM alone, who has no partner, HIS is the dominion and HIS is praise and in HIS hand is all good and able to do all things.

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ABBREVATIONS USED

AGIBPs – Agro-industrial by-product

DIP – Degradable intake protein

EPA – Environmental Protecion Agency

GHG – Green house gas

GWP – Global warming potential

g/d- Gramme per day

mg/L – Milligramme per litre

mmol/L – Millimole per litre

PNAS - Proceedings of National Academy of Sciences

P.thonningii – Piliostigma thonningii

PTLM - *Piliostigma thonningii* leaf meal

PTPM - *Piliostigma thonningii* pod meal

SCFAs – Short chain fatty acids

UIP - Undegradable intake protein

v/v- Volume per volume

ABSTRACT

This study was conducted to estimate the effect of *Piliostigma thonningii* leaf (PTLM) and pod (PTPM) meals on growth performance, nutrient digestibility, nitrogen balance, rumen metabolites, methane emission and the economic benefit of including PTLM and PTPM in diet of Yankasa lamb rams. A total of eight lamb rams weighing 18 to 23kg on average were randomly assigned to four dietary treatments containing PTLM and PTPM of 13.91 and 13.59% crude protein in a complete diet. The diets containing 0, 5, 10 and 15% inclusion levels of PTLM and PTPM were fed to the lamb rams at 4% of their body weights in a trial period that lasted 90days for both PTLM and PTPM in a 4x4 Latin Square Design. Results obtained showed that the average values for weight gain, average weight gain and feed conversion ratio respectively were significantly ($P<0.05$) affected by inclusion levels of PTLM and PTPM. Lamb rams fed 5% inclusion of PTLM had corresponding values of 2.37kg, 169.64g/day and 5.79 compared to PTPM which had 2.63kg, 187.50g/day and 7.50. The crude fibre, ether extract and nitrogen free extract digestibility in Yankasa lamb rams were significantly ($P<0.05$) affected by varying inclusion levels of PTLM and PTPM. Nitrogen balance (nitrogen intake, nitrogen absorbed, nitrogen retained and nitrogen retained as % intake) in Yankasa lamb rams was significantly ($P<0.05$) affected by PTLM and PTPM inclusions across the dietary treatment. Fitting into methane emission models, for model 1, the result revealed that lamb rams fed 0% (1.52MJ/day) and for model 2, those fed 5% (4.32L/day) inclusion of PTLM had the least methane production. While lamb rams fed PTPM inclusions were significantly ($P<0.05$) affected for model 1 and model 2 with those fed 5% (1.55MJ/day) and 0% (11.24L/day) inclusion levels respectively having the least methane production. The pH and total volatile fatty acid were not significantly ($p>0.05$) affected across the dietary treatment of PTPM inclusions but significant ($p<0.05$) effect was recorded for the ammonia nitrogen. The cost of the diet reduces with increasing PTLM and PTPM inclusions although best performance was observed among animals fed 5% inclusion level of PTLM and PTPM respectively in this study. PTLM and PTPM at 5% inclusion in a complete diet can be used to alleviate the problem of feed scarcity in terms of quantity and quality in the dry season period and also to enhance efficient performance of Yankasa lamb rams. Furthermore, the inclusion of PTLM and PTPM in diet of Yankasa lamb rams decreased quantity of methane released into the environment.

CHAPTER ONE

1.0 INTRODUCTION

Small ruminants have the potential of converting highly fibrous feeds such as grasses, legumes, forages, farm wastes and crop residues of poor quality and unsuitable for human consumption to body tissue (Fajemisin *et al*., 2010). Also, small ruminants serve a multitude of functions ranging from food to organic fertilizers that are essential to human life in both rich and poor countries (Gatenby, 2002). Small ruminants are important part of global agricultural economy such that they play a major role in many local economies (Weaver, 2005). Traditionally, sheep and goats have served as means of ready cash and a reserve against skins that can feed the local leather industry. Sheep have high fertility and reproductive rates (Tona, 2011). However, seasonal variation in the supply of forage is one of the problems facing sheep production in Nigeria. This problem is more pronounced in Northern Nigeria during the dry season, when the rangelands are completely over-grazed.

Researchers attempted to address the issue of feed scarcity through the use of various browse plant species such as; *Ficus thonningii* (Yousuf and Ogundun, 2005), *Daniellia oliveri* (Isah *et al*., 2014) and *Tithonia diversifolia* (Odedire and Oloidi, 2014). The supply of adequate feeds in terms of quality and quantity for small ruminant production becomes critical during the dry season period (Adegbola, 2002); this results in the assessment of the feeding value of the range plants which has been recently recognized as having the potential to address the problem of feed scarcity to ruminant livestock. Jimoh and Oladiji, 2005 reported the utilization of *Piliostigma thonningii* seeds as a cheap source of protein, energy, minerals and antioxidant supplement for ruminant livestock in southwest Nigeria.

In the dry season, grasses and browse plants dry up and there is dehydration with high degree of lignification which results in loss of weight in grazing animals. Therefore, there is need to integrate feeding of *Piliostigma thonningii* leaf and pod meal to serve as protein sources which is usually low in feed during the dry season and also to improve feeding of sheep. Ruminants have become extremely efficient at converting food such as grass, silage, hay and concentrates into agricultural products such as milk and meat. At the same time, feed quality, ration formulation and herd management have all contributed to the overall increase on productivity.

However, one of the by-products of rumination, the process by which animals such as sheep and cattle digest food, is methane – a powerful greenhouse gas (GHG) which is produced during the anaerobic fermentation of hydrolyzed dietary carbohydrates in the rumen and represents an energy loss to the host besides contributing to emissions of greenhouse gases into the environment (Raghavendra and Osamu, 2007).Greenhouse gases are gases that trap heat in the atmosphere. They include carbon dioxide, methane, nitrous oxide and fluorinate gases such as hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride, which are emitted from a variety of industrial processes (EPA, 2016).

1.1 Justification of the study

The major constraint to ruminant livestock production in the tropics is the availability of cheap and quality feedstuffs, especially in periods of drought or dry season. The increasingly expensive nature of most feed ingredients has resulted in reduced livestock production activities by subsistence farmers who constituted the majority of the livestock holder in the typical sub-Saharan Africa, and this has impact negatively on the available

animal protein for human consumption (Odedire and Oloidi, 2014). Nutrition is one of the most important aspects of livestock production which can be used to enhance animal productivity. Minister for Agriculture and Rural Development released a census of livestock in the Country by National Agricultural Sample Survey which indicated that Nigeria is endowed with an estimate of 19.5 million cattle, 72.5 million goats, 43.1million sheep, 7.1 million pigs and 28, 000 camels (Ogeh, 2016).

Yankasa sheep is a medium sized animal in addition to its hardiness and ecological spread in Nigeria. This breed of sheep is very popular among sheep farmers, most especially in the Northern Nigeria. At the smallholder level, sheep play a very important role in the socioeconomic and cultural life of the farmers. Sheep produce skin that can feed local leather industries. The sheep skin has been estimated at 7,500 tonnes annually (FAO, 2004).

Under traditional system, the growth performance of sheep has remained generally low due to poor management, which is related to low plane of nutrition. This problem results from seasonal changes which affects natural rangelands and the availability, palatability and nutritive value of feedstuffs, especially in dry season period (Odedire and Oloidi, 2014). Ruminant livestock in Nigeria cannot utilize many browse plants in the rangelands due to high contents of anti-nutritional factors, high fibre levels, and low palatability of leaves. Although some of these plants may be of high nutritional quality, but they are hardly utilized by farmers for the purpose of feeding livestock, despite their abundance in the rangelands. There is therefore need for exploring the potentials of such browse plants in feeding ruminant livestock in Nigeria. One of such plants is camel's foot (*Piliostigma thonningii*), which has the potential of solving the problem of feed scarcity to livestock, especially during dry season period, because it exist throughout the year.

Presently, there is global concern about the climate change, which is known to affect farmers negatively (EPA, 2016). Emissions from livestock rearing and related practices such as storage of liquid manure are believed to be the highest contributors of Green House Gases compared to those from the soil, chemical fertilizers, burning of fossil fuels and others. For ruminant livestock, emissions of nitrous oxide, methane and carbon dioxide from enteric fermentations of the rumen serve as significant pathways of losses of nitrogen, energy and organic matter that undermine efficiency and productivity of livestock (EPA, 2016). About 44 percent of emissions from livestock are in the form of methane, while the remaining part is almost equally shared between nitrous oxide (29%) and carbon dioxide (27%) (FAO, 2016). Calculating the exact amount of these gases emitted by ruminant livestock reared under crop-livestock system requires the use of sophisticated tools, which are practically unavailable in Nigeria. However, these gases can be estimated through the use of some models designed for ruminant livestock.

1.2 Objectives of the study

1. To determine growth performance, nutrient digestibility and nitrogen retention in Yankasa lamb rams fed diets containing inclusion levels of *Piliostigma thonningii* leaf and pod meals.

2. To estimate methane emission by Yankasa lamb rams fed diets containing inclusion levels of *Piliostigma thonningii* leaf and pod meals.

3. To determine the cost-benefit analysis of including *Piliostigma thonningii* leaf and pod meals in the diets of Yankasa lamb rams in Northern Guinea savannah.

1.3 Research hypothesis

$Ho_{1:}$ Diets containing inclusion levels of *P. thonningii* leaf and pod meals have no effect on growth performance, nutrient digestibility and nitrogen retention in Yankasa lamb rams.

Ha_1: Diets containing inclusion levels *P. thonningii* leaf and pod meals have effect on growth performance, nutrient digestibility and nitrogen retention in Yankasa lamb rams.

Ho_2: Feeding diets containing inclusion levels of *P. thonningii* leaf and pod meals have no effect on methane emission by Yankasa lamb rams.

Ha_2: Feeding diets containing inclusion levels of *P. thonningii* leaf and pod meals have effect on methane emission by Yankasa lamb rams.

Ho_3: Diets containing inclusion levels of *P. thonningii* leaf and pod meals have no economic benefit in Yankasa lamb rams.

Ha_3: Diets containing inclusion levels of *P. thonningii* leaf and pod meals have economic benefit in Yankasa lamb rams.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Population and Distribution of Sheep in Nigeria

Among all the livestock that makes up the farm animals in Nigeria, ruminants, comprising sheep, goats and cattle, constitute the farm animals largely reared by farm families in the country's agricultural system. Minister for Agriculture and Rural Development released a census of livestock in the Country by National Agricultural Sample Survey which indicated that Nigeria is endowed with an estimate 43.1million sheep (Ogeh, 2016). The larger proportion of the animal is found in the northern region of the country. Available breeds of sheep in the country are mainly indigenous and these are the West African Dwarf (WAD) sheep, Balami, Uda and Yankasa. Out of these four major breeds of sheep in the country, the WAD breed is common to southern region against the widespread of Balami, Uda and Yankasa breeds in the northern region of the country. (Adebowale, 2012).

Concentration of Nigeria's livestock-base in the northern region is most likely to have been influenced by the ecological condition of the region which is characterized by low rainfall duration, lighter sandy soils and longer dry season. This submission is predicated by the fact that drier tropics or semi-arid regions are more favourable to the ruminants, Notwithstanding this situation, certain breeds of sheep particularly the West African Dwarf (WAD) species, are peculiarly adapted to the southern (humid) region of the country and are commonly reared by rural households in the region (Adebowale, 2012).

2.1.1 Physical characteristics of Yankasa breed of Sheep

The Yankasa breed is widely distributed in the northern part of Nigeria. It is intermediate between Uda and West African Dwarf sheep. The coat colour of Yankasa is typically white

with black patches around the eyes, ear, muzzle and sometimes the feet. The rams have curved horns and heavy hairy white mane. Some of the ewes have tassels on the neck (Adu and Ngere, 1979). Mature weights are 25 – 40 kg for ewes and 35 – 50 kg for rams. Characteristics analysis of sheep in the country, especially among the Fulani pastoralists showed that ewes had approximately 120% fertility rate, 12% rate of twinning and 25% lamb mortality rate at 3months old. Sheep productivity index puts lamb weight at 0.327 kg at a weaning age of 90 days, and 0.490 kg at a weaning age of 180days per ewe per year (Adebowale, 2012).

2.1.2 Importance of small ruminants in Nigeria

Ruminants play significant roles in the economic wellbeing of Nigerians in various ways. Economically, the animals serve as source of income earning to major ruminants dealers-sellers of live animals and butchers. Ruminants generate employments and create markets for larger number of people who explore animal's product and by-products for economic gains. Meat constitutes the foremost animal product that is highly explored by the Nigerian households, particularly for direct consumption (ITA, 2004). Sheep are much more easily acquired by individuals in relation to cattle owing to market price differentials between the small and large ruminants (Adebowale, 2012). Nigerian livestock resources (Jabbar, 1994) puts the total livestock value at ₦60 billion, based on mid-1991 market prices and as indicated by (ITA, 2004), account for as much as one third of the country's agricultural gross domestic product (GDP). Hides and skin are used in making clothes, footwear, rugs, and other products. By-products from the slaughter of sheep are also of value, for example sheep tallow can be used in candle and soap making, sheep bone and cartilage has been used to furnish carved items such as dice and buttons as well as rendered glue and gelatine

(Simmons and Carol, 2001). Sheep do not require the expensive housing such as that used in the intensive farming of chickens or pigs. They are an efficient use of land; hence roughly six sheep can be kept in the space that would suffice for a single cow or horse (Smith *et al*., 1997) .

2.1.3 Constraints of small ruminant production in Nigeria

Small ruminants in the humid zone of West Africa roam around and eat natural pastures and kitchen wastes which contain low crude protein, high fibre and lignin contents (Adegun and Aye, 2013; Aregheore, 2000). The low nutritional contents of these feedstuffs greatly hampers the productivity of these animals especially during the dry season when the crude protein content of the feedstuffs could be as low as 2% (Sarwatt *et al*.,2004). This leads to slow growth rate, loss of body weight, low birth weight, predisposition to diseases as well as maternal and child death. Cost of supplementary feeding and non-availability of forages during the dry season are the main challenges of efficient livestock production in Nigeria (Adebowale, 2012) . Based on the need for adequate feeding, it is believed that about 85% of cost of livestock production is feeding therefore the need to implore the use of browse plants becomes necessary as browse plants are available throughout the year (Adebowale, 2012). The poor economic status of the ruminant keepers in the country however makes it extremely difficult to build the livestock industry. Also, adopted poor management systems for farm animals in Nigeria and most other developing countries, certainly accounted for the poor production performance of the local ruminant breeds. Pests and diseases portend a major risk to livestock development in Nigeria, as incidence of pests and diseases are common in the country's livestock system (Adebowale, 2012).

2.1.4 Small ruminant production systems

In general, farm animals are poorly managed in Nigeria's agricultural systems owing to the fact that the animals are mostly managed on free range/extensive system and semi-intensive system. Under the free range system, the animals move about freely to feed on forages/grasses, which are abundantly available during the rainy season and on other feed source such as left over foods or kitchen wastes and refuse dumps (Adebowale, 2012). This is a system of production where animals are allowed to graze or browse on large areas of land that are marginal in nature and not suitable for agricultural use (Otaru and Iyiola Tunji, 2015). The animals raised under this system are very destructive to crops. Animals are often prone to disease, risk of theft and parasites infestation (Weaver, 2005). Hardly are the animals provided supplementary feeds and even shelter by their keepers. Some households or livestock keepers on the other hand maintain semi-intensive management system whereby the animals are provided shelter and kept indoors for security purpose. The animals somehow have their movements regulated and as such are released to fend for themselves in the early and late hours of the day, after which they are kept indoors over the night. Although, hardly are the animals under semi-intensive management provided supplements or essential ration for consumption, efforts are made by their keepers to feed them with by-products from farm produce, especially during dry season when pasture are hardly available for free grazing (Adebowale, 2012). The Balami, Uda, Yankasa; and Sokoto Red breeds of the small ruminants highly prized for social ceremonies and prestige are thus kept on a modified intensive management system whereby the animals are mostly tethered or kept in a guarded enclosure and fed on cut-and-feed forages and by-products of farm produce (Adebowale, 2012). Sheep and goats under this system are usually managed by government establishments with concrete floors, while in villages the floor is usually

rammed with clay or earth. The supporting materials could be made from plant materials or concrete walls laid round the pen. The roof is made of thatch materials in villages and corrugated iron sheets in cities and government or university farm centres. Feeding and watering troughs are provided based on the stock strength. The animals are often fed with concentrates and mostly on roughages (Ozung *et al*., 2011).

2.1.5 Nutrient requirement of sheep

2.1.5.1 Water

Functions of water in the animal body include; Helping to digest food, lubricating, transporting waste from the body. Water is required for the maintenance of body temperature and functions therefore water must always be available to animal (Diego, 1994). To maintain comfort in hot climates, small ruminant can conserve water losses from the body by decreasing losses in urine and faeces. Environmental temperature, water content of feed consumed, amount of exercise, stage of production, salt and mineral content of the diet affect water intake of animals. Animals grazing lush pastures consume much lower quantities of water than those feeding on dry hay still, sheep should be provided limited access to fresh, clean, non stagnant sources of water as they are among the most efficient of domestic animals in the use of water, sheep require two to six litres of water per day, depending on age, physiological status, and type of feed and ambient temperature (Aribido *et al*., 2017).

2.1.5.2 Energy and Fat

The major sources of energy for small ruminants are usually pastures and browses, hay, and grains. A total digestible nutrient (TDN) is a broad term used to express the energy value of

a feed or ration. As the amount of TDN increases in a ration, the rate of gain normally increases. Therefore, feed efficiency and overall performance are determined to a large extent by the level of TDN or energy in the ration (Diego, 1994). Fats contain about 2.25 times as much digestible energy as the carbohydrates in grain. Fats have been added to rations to reduce the health stress of eating dusty and/or very finely processed feeds, to reduce the incidence of bloat, or to increase the energy density in the ration if the price of grain is high, fat addition may be economical for increasing energy and thus performance. When commercial feed fats are used to increase energy in feedlot diets they are usually added at the rate of 2 to 5 percent of the diet's total dry matter (Marx, 2014).

2.1.5.3 Protein

Proteins are essential for the repair of worn out tissues and the building of new ones. Young and nursing (milking) animals in particular need proteins. Oil seed cakes and legume hays (harawa) are good sources of protein (Aribido *et al*., 2017). An adequate amount of protein must be supplied if rapid growth and high production are to be obtained (Diego, 1994). Protein is required for most normal functions of the body, hence its deficiency in the diet of animals predisposes them to variety of serious and even fatal ailments, also, feed intake and dietary digestibility are reduced if dietary crude protein is less than 6%. Mildford and Minson,1967; Tona, 2011 recommended range 7-8% as the least value required by ruminants for efficient performance. Protein is required both as a source of nitrogen for the ruminal bacteria and to supply amino acid for protein synthesis in the body of animals. Feeding adequate to slightly greater amounts of protein than required appears to aid in the control (both resistance and resilience) of internal nematode parasites (David, 2014).

2.1.5.4 Minerals

The essential minerals for sheep and goats are calcium, phosphorus, and salt (Diego, 1994). Major minerals likely to be deficient in the diet are salt, (sodium chloride), calcium, phosphorus and magnesium, most forages are high in calcium, it could be low only if high grain diet are fed. The ratio of calcium to phosphorus in the diet is important and should be kept at ratio 2 to 1 (Lunginbuhl, 2015). Calcium is a necessary constituent of the bones and teeth and is essential for regular heart action and muscular activity. Phosphorus is involved in chemical reactions which release energy in the body. Calcium and phosphorus are interrelated while an adequate supply of each is required, they must also be present in the ration in the proper proportion (Diego, 1994). Also, trace minerals likely to be low in diet are copper, zinc and selenium, with selenium being the most deficient, therefore, mineralized salt that include selenium should be provided to small ruminants at all time (Lunginbuhl, 2015).

2.1.5.5 Vitamins

Vitamins are compounds which are necessary for normal growth, health, and reproduction. Small ruminants require many vitamins, just as other animals do. However, their dietary vitamin requirements are relatively simple because of the nature of the feeds they ordinarily consume and the synthesis of vitamins in the rumen (Diego, 1994). The rumen micro-organisms manufacture all of the B vitamins and vitamin K hence, vitamin synthesis in the rumen is sufficient for growth and maintenance. Under most conditions, ruminants with functioning rumens do not require supplemental B vitamins or vitamin K in the diet (UMN, 2017). The vitamins most likely to be deficient in the diet are vitamin A and D, vitamin A results in poor calcium absorption leading to rickets, a condition where bones of young

animals and joints grow abnormally. Vitamin A is not contained in forages, but carotene found in green, leafy forages is converted into vitamin A in the body, in addition, vitamin A stored in the liver of small ruminants when intake exceeds requirement vitamin C is synthesized in the body tissues in adequate quantities to meet needs (NRC, 1985).

2.2 Feed resources for ruminant livestock in Nigeria

2.2.1 Grasses

Given the distinct nature of the ruminant's stomach, the farm animals heavily depend on forage or roughage as major feeds. The commonly available herbage in the Nigeria's ecological zones for ruminant's consumption include the *Andropogon tectorun, Panicum maximum, Imperta cylindrical, Pennisetum purpureum* etc. These grasses, which are fibrous in nature, are rich in cellulose and provide the ruminants a high level carbohydrate and some measures of vitamins and minerals. These grasses grow rapidly during the rainy season and as such become abundant for the ruminant's consumption (Adebowale, 2012). **S**easonal fluctuations in nutritive value make sustainable gains in production from good management and disease control programs unrealistic (Alli-Balogun *et al.*, 2003). The crude protein contents of principal forages such as gamba (*Andropogon gayanus*) and guinea grasses (*Panicum maximum*) fall to as low as 2% for the most part of the dry season, alongside reduced mineral and energy contents (Pond *et al*., 1995; Asaolu *et al*., 2012).

2.2.2 Legumes

crop residues and agro-industrial by-products that are used in supplementing principal forages during the usually extended dry season are usually fibrous, low in digestibility and devoid of most essential nutrients which are required for increased rumen microbial

fermentation and improved performance of the host animal (Osuji *et al*., 1995; Lanyasunya *et al*., 2006). Alternative to mitigate the effect of dry season feeding was the establishment of fodder bank whereby legumes are established and properly managed in a concentrated unit (Otesile *et al.,* 1983), all legumes except soyabeans are reported to have protein content ranging from 20-25% (Apata and Ologhobo, 1994) whereas *P. thonningii* seed which is a leguminous browse plant has a higher crude protein than this range making legumes a cheap source of protein and also encourages it use in some feed formulations (Jimoh and Oladiji, 2005).

2.2.3 Crop residues

Crop residues refer to the fibrous parts of cereals, sugar cane, roots and tubers, dried fruits, etc. Their common features include the fact that they comprise the parts that are not consumed by humans after the harvest, and also they have low feed value for animals and a very low or non-existent feed value for monogastric animals. Yet they are used as feed, since these creatures are able to digest them (FAO, 2014). The declining grazing land as a result of the ever increasing land cultivation for arable crop production, utilization of fodder from crop residues compensates for non-availability of grasses during the off-season (Adebowale, 2012).

2.2.4 Browse plants

Browse plants have been found to be of significant potential in terms of adoptability, productivity and acceptability for ruminants in order to balance the difficulties of feed shortages during the dry season (Hutagalung, 1981). Browse quality and availability vary greatly from wet season to dry season (Ogunbosoye and Babayemi, 2010). In Nigeria for example, traditional herdsmen and other pastoral groups habitually cut down branches from

various browse tree species, making them available to livestock during the dry season when no other forage is available (Yahya *et al.,* 2000). A number of such browse plants worldwide serve as alternative feedstuffs for livestock (Ammar *et al*., 2004; Aregawai *et al.*, 2008; Rinehart, 2008; Fayemi *et al*., 2011).

Animals under semi-intensive and free-range systems have been observed feeding on them, especially during the dry seasons characterized by lean feed resources (Apori *et al*., 2007; Isah *et al*., 1999 and 2012). Thus, browse plants constitute one of the cheapest sources of feed for livestock, especially ruminants in the tropics (Okoli *et al*., 2003; Ahamefule *et al*., 2006) and are good sources of essential nutrients such as proteins, carbohydrates, vitamins and minerals which are frequently inadequately represented in tropical grass pastures (Okoli *et al*., 2014). Forage on the other hand hardly become available during the dry season for consumption of the ruminant and coupled with the declining grazing land as a result of the ever increasing land cultivation for arable crop production, alternative feed sources for the animals becomes essential (Adebowale, 2012).

2.2.4.1 Importance of browse plants in ruminants

Browses are important in providing nutrient to grazing ruminants in arid and semi-arid environments where inadequate feeds are a major constraint for livestock production. Tree fodders are important source of nourishment for grazing ruminants and as supplements to improve the productivity of herbivores fed on low quality feeds. Browse forages form part of the complex interactions between plants, animals and crops, the positive aspect of which is to help balance a plant-animal-soil ecosystem from which there is sustainable source of feeds (Andrew *et al*., 2017). The potential value of browse trees lies in the provision of protein, vitamins and also the mineral elements that are lacking in grassland pastures during

the dry season (Ogunbosoye and Babayemi, 2010). Apart from being browsed, woody plants have always played a significant role in human lives. With regard to crop production, farmers in semi-arid West Africa have traditionally spared desired species are valuable because of the ability to improve soil fertility through nitrogen fixation, and also because of the reverse vegetation cycle of this tree, that produces green leaves in the dry season for feeding animals, and they in turn spread manure on the field. In the rainy season the species lose their leaves, resulting in no shading effects on the crop. Other species maintained in the croplands have different socio-economical importance (edible leaves or fruits, ethno-medicinal use or shade) and reduce evaporation from the fields. Overall, the multiple uses of woody plants include soil maintenance and protection against erosion and dune stabilisation (as windbreaks), source of energy (fire wood), construction material and with their shade reduced water loss from the soil and lower temperature. The trees serve as source of income through the sale of leaves, fruits and wood, and ethno medicinal and veterinary uses are common (Sanon, 2007).

2.2.4.2 Nutritive value of browse plants

Compared to grasses leguminous browse plants have both higher digestibility and higher intake and their nutritive value tends to remain higher as they mature. The foliage of browse plants are the reservoir of valuable nutrients such as proteins, vitamins and minerals that are not found in grasses and other crop residues, that can be critically important most especially during the dry season (Ogunbosoye *et al*., 2015). *Piliostigma thonningii* leaf have been used as supplementary feed with *Panicum maximum* which enhanced the digestibility of West African Dwarf Sheep (Tona, 2011), also, *acacia nilotica* leaves and pods have been used by researchers and stock owners as a supplement to poor quality

roughages resulting in appreciable live-weight gains (Tanner *et al*., 1994; Sawe *et al*., 1998). The following are browse plants and their chemical composition (crude protein, crude fibre and acid detergent fibre respectively); *Gliricidia sepium* (20.54, 15.86 and 29.39%), *Leucaena leucocephala* (18.56, 16.77 and 47.72%), *Moringa olifera* (22.74, 9.55and 27.58%) *Artocarpus heterophyllus* (15.08,19.64 and 58.02%) (Astutia *et al*., 2011).

2.2.4.3 Constraints of browse plants

The utilisation of browse is limited by the high lignin content and the presence of anti-nutritional factors, which may be toxic to ruminants. Many browse species have chemicals that appear to be produced for the purpose of deterring invasion or consumption of their leaves by microbes, insects and herbivorous animals. The most important cited is tannin, which is shown to decrease the digestibility in browse fodders. Tannins are a group of polyphenolic substances with the ability to bind protein in aqueous solution. They are classified into two groups: hydrolysable or condensed tannins, and are considered to have both adverse and beneficial effects depending on their concentration and nature (Makkar, 2003; Silanikove *et al*., 1996). While tannins are the best known of the anti-nutritional factors of browse, there is a long list of secondary compounds: cyanide, nitrate, fluoroacetate, cyanogenic glucosides, saponins, oxalates, mimosine and various sterols (Leng, 1997). However, the toxic compounds seem to become of significance nutritionally only when the plant constitutes a high proportion of the diet (Sanon, 2007).

2.2.5 Other feed resources

2.2.5.1 Agro-industrial by products

Agro-industrial by-products (AGIBPs) refer to the by-products (e.g. olive cakes, molasses, tomato pulp, fruit pulps such as grape marc and citrus pulp) derived in the industry due to processing of the main products (Ben Salem, 2010), Products generated from industrial processing (cotton, groundnut, soybean, wheat, rice and sugar cane) and those generated by small-scale processing (major local cereals: millets, sorghum and maize) (FAO, 2014). Cotton seed cake is a by-product of oil extraction from cotton seed, it is a common source of protein for ruminants notably in cotton producing areas. The protein content is highly variable as it depends on the amount of dehulling and on the efficiency of oil extraction. The range of protein content goes from 30% DM for non-dehulled cotton seed cake to 50% for fully dehulled cakes, lower and higher values than these extremes have been recorded (Heuze *et al* 2013). Also the nutrient composition (crude protein, crude fibre and acid detergent fibre) of corn starch residue which is also an AGIBPs includes; 10.08, 1.50 and 42.27% respectively (Asaolu *et al*., 2012).

2.2.5.2 Cassava peels

It has become imperative to explore the use of other sources like Cassava peels considered as waste**.** Cassava peels can represent 5 to 15% of the root .They are obtained after the tubers have been water-cleansed and peeled mechanically (Aro *et al*., 2010). Cassava peel has nutrient composition (crude protein, crude fibre and acid detergent fibre) of 5.63, 20.92 and 14.22% respectively (Asaolu *et al*., 2012).They may contain high amounts of cyanogenic glycosides and have higher protein content than other tuber parts. Cassava peels are highly digestible products, with reported values of 78% and 81% for DM (dry matter)

and OM (organic matter) total tract digestibility respectively. Dry matter degradability is also high, with reported values more than 70% (Heuze *et al*., 2016).

2.2.5.3 Yam peels

Crop by-products includes; maize sievate cassava sievate, fried garri sievate, peels derived from corn and cassava, other peels can also be gotten from; yam, plantain and sweet potato (Heuze *et al*., 2016). crop residues are devoid of most essential nutrients which are required for increased rumen microbial fermentation and improved performance of the host animal (Osuji *et al*., 1995; Lanyasunya *et al*., 2006). The resultant effects, as widely acknowledged, are reduced intake, DM digestibility and productivity of the animals.

2.3 Background information on *Piliostigma thonningii*

2.3.1 Origin of *P. thonningii* trees

P. thonningii is native to tropical Africa. It is widespread in the Sudano-Guinean region from Senegal eastward to Eritrea and occurs southward to Namibia, Botswana, Mozambique and South Africa. It also occurs in Yemen (Lemessa, 2010). *P. thonningii* is common in open woodland and wooded grasslands of sub-humid Africa at medium to low altitudes. It is found throughout tropical Africa except in Somalia (Orwa *et al*., 2009). *P. thonningii* is a deciduous or evergreen shrub or tree with a rounded crown, it can grow 3 - 15 metres tall (Ruffo *et al*., 2002). *Piliostigma thonningii* is a leguminous plant found mostly in woodland habitats (Lock and Simpson, 1999). *Piliostigma thonningii* is a deciduous tree with a single stem which has a common name; camel's foot that results from its large, simple, two-lobed leathery leaves which resemble a camel's foot. Locally, the seed is called Abefe in the Yoruba land (Nigeria). Other names include Monkey bread,

Kalgo (Hausa) and Okpoatu (Ibo) (Jimoh and Oladiji, 2005). The tree is highly utilized by local people (Mutshinyalo and Sisulu, 2010). *Piliostigma thonningii* has dark reddish brown flattened oblong pods about 30-70mm long which sometimes break up into one-seeded pieces after falling from the trees. The pods are nutritious and relished by cattle and antelopes (Orwa *et al.,* 2009). Different parts of *Piliostigma thonningii* have been described useful medicinally.

2.3.2 Botany of *P. thonningii* trees

P. thonningii is a tree with a rounded crown and a short but often crooked bole. The Twigs are rusty-hairy and the bark is rough and longitudinally fissured, it is creamy-brown when fresh and grey-brown later. *P. thonningii* has leathery green leaves up to 15 x 17 cm, it is bi-lobed one eighth to one third the way down with a small bristle in the notch, glossy above and heavily veined and somewhat rusty-hairy below. The Flowers are with 5 white to pink petals, pendulous, it is unisexual with male and female usually on separate trees. The ovaries are topped by a thick flattened globose stigma. The Pods are indehiscent up to 26 x 7 cm with rusty-brown hairs that wear off as the pods mature, becoming somewhat contorted as they age. The pods persist on the tree but finally fall and decay on the ground to pea-sized seeds; these seeds are surrounded by an edible pulp (Orwa *et al*., 2009).

P. thonningii roots deeply. The generic epithet *Piliostigma,* means cap-like stigma. The specific epithet commemorates Peter Thonning, the Danish plant collector who collected the type in that portion of Danish Guinea that is now part of Ghana. *Piliostigma* was distinguished from Bauhinia by its unisexual flowers and indehiscent pods (Orwa *et al*., 2009). *Piliostigma* comprises 3 species in tropical Africa, Asia and Australia. *P.thonningii* is frequently confused with *P. reticulatum* due to similarity in appearance, but the former

has larger leaves with hairs on the lower surface, and usually occurs in less dry areas(Lemessa, 2010).

2.3.3 Description and distribution of *P. thonningii* trees

P. thonningii grows in savannah regions that are moist and wooded grassland in low to medium altitudes. It is widely distributed in Africa and Asia. It is found growing abundantly as a wild uncultivated tree in many parts of Nigeria such as Zaria, Bauchi, Ilorin, Plateau, Lagos and Abeokuta (Schultes and Hofmann, 1973). It is sensitive to frost, it grows on any soil type, but heavy clayey soils or medium loamy soils are preferred. *P. thonningii* is common in secondary and gallery forest, woodland, wooded grassland and bushland, often in river valleys, and in undisturbed locations. It flowers from December to February. *P. thonningii* occurs from sea level up to 2200 m altitude in areas with an average annual temperature of 20–21°C, an average annual rainfall of (400–) 600–1200 (–1500) mm, and a dry season of 6–8(–11) months (Lemessa, 2010).

P. thonningii is a deciduous tree up to 10(–40) m tall with a single stem, sometimes shrubby with bole branchless for 2–3 m, twisted, up to 30(–35) cm in diameter, it has a common name; camel's foot that results from its large, simple, two-lobed leathery leaves which resemble a camel's foot. The outer bark is rough, longitudinally fissured, dark brown to grey or black while inner bark is fibrous, pink to dark red-brown when cut, crown spreading and branches with rusty-brown tomentum, somewhat glabrescent later (Lemessa, 2010). The male inflorescence very narrowly pyramidal up to 25 cm × 5.5 cm while the female inflorescence is about 7 cm long, few-flowered with axes brown-tomentellous. Flowers are unisexual with fragrant, calyx is copular about 1–2.5 cm long, it is brown-tomentellous with five lobes. The petals are obovate, they five in number and about 1–2.5

cm long, they are wrinkled, margin strongly undulate and white to lilac or pink in colour. The stamens are scarcely reaching the throat of the flower, reduced to staminodes in female flowers with ovary brown-tomentose, rudimentary in male flowers, style is very short or absent and stigma capitates (Lemessa, 2010).The flowers are not showy. Flowers are followed by large, thick, reddish brown, non-splitting pods about 30–70 mm (Mutshinyalo and Sisulu, 2010). Twigs are rusty-hairy. The bark is dark brownish grey with a rough surface (Orwa *et al* 2009). The tree is highly utilized by local people and the fresh leaves can be chewed to reduce thirst (Mutshinyalo and Sisulu, 2010).

2.3.4 Characteristics of *P. thonningii* trees

The moisture content of *P. thonningii* (6.71 ± 0.40%) is lower than that of most legume seeds (Giani, 1993; Temple *et al.*, 1991), this implies that the shelf life for this seed will likely be longer than that of most legumes. The level of iron amongst all minerals analyzed for *P. thonningii* was found to be the highest (Jimoh and Oladiji, 2005).The bast fibre of *P. thonningii* is recorded to be long and strong. The heartwood is pinkish to dark brown, the sapwood pale brown. The wood has an air-dry density of about 750 kg/m³ (Mandibaya and Chihora, 1999). The fruit contains per 100 g edible portion: water 5.0–9.8 g, energy 1089–1185 kJ (260–283 kcal), protein 6.3–6.9 g, fat 1.8–3.2 g, carbohydrate 54.6–58.9 g, Ca 360 mg, Fe 40 mg (Irvine, 1961). Pod meal is said to be pleasantly scented. The in-vivo degradability of dry matter and crude protein in Holstein-Friesian steers was 33.4% and 29.8%, respectively, and it was concluded that the meal could be a useful feed supplement to cattle grazing poor quality forage during the dry season (Mandibaya and Chihora, 1999). Per 100 g seeds from Nigeria contained: moisture 6.7 g, crude protein 30.3 g, crude fat 1.4

g, carbohydrate 23 g, crude fibre 35.0 g. Dried leaves contain per 100 g: water 9.3 g, protein 9.6 g (Mandibaya and Chihora, 1999).

Screening of the seeds revealed the presence of saponins, flavonoids, phenolics, anthraquinones and glycosides (Jimoh and Oladiji, 2005). Root, bark and leaf extracts showed antiviral activity against Herpes simplex virus type 1 and 2 (HSV-1, HSV-2), HIV and different strains of influenza and syncytial viruses (Lemessa, 2010). The roots, leaves and stems showed in-vitro activity against the tapeworm *Hymenolepis diminuta* ('rat tapeworm') (Lemessa, 2010). Stem bark extracts exhibited antibacterial activity against *Bacillus subtilis*, *Corynebacterium pyogenes*, *Escherichia coli*, *Proteus vulgaris*, *Shigella dysenteriae* and *Staphylococcus aureus* . An ethanolic extract of the stem bark induced persistent contractions of the isolated guinea pig ileum and D-3-O-methylchiroinositol isolated from the stem bark showed anthelmintic activity against *Haemonchus contortus* larvae from faecal samples of infected lambs (Asuzu *et al*, 1999). Bark extracts have shown in-vitro larvicidal activity against intestinal parasites of cattle. An ethanolic extract of the bark showed anthelmintic activity. The presence of alkaloids is reported for the bark (Asuzu and Onu, 1994). Butanol and ethyl acetate fractions of the leaf extract exhibited strong antioxidant activity (Aderogba *et al*, 2004). Piliostigmin (a new 2-phenoxychromone) and three C-methylflavonols (6, 8-di-C-methylquercetin 3-methyl ether, 6-C-methylquercetin 3,7-dimethyl ether and 6,8-di-C-methylquercetin 3,7-dimethyl ether) were isolated from the leaves and some of these C-methylflavonols have shown anti-inflammatory and antibacterial activity. The leaves and the fruits contain l-tartaric acid (Ibewuike *et al.*, 1996; Ibewuike *et al*., 1997).

2.3.5 Nutritive value of *P. thonningii* trees

The pods of *P. thonningii* are nutritious and relished by cattle and antelopes and it is a preferred browse species of the African elephant (*Loxodonta africana*), the fruits are also taken in considerable quantities (Orwa *et al*., 2009). An experiment carried out to evaluate the rumen fermentation parameters and microbial profile of red Sokoto goats fed threshed sorghum top supplemented with browse foliages such as *P.thonningii, Daniellia oliveri, Afzelia africana, Pterocarpus erinaceus* and *Annona senegalensis* revealed that goats on *P. thonningii* had highest ruminal pH (7.67) (Isah *et al*., 2014). In the qualitative determination of chemical and nutritional composition of *P. thonningii* carried out by (Jimoh and Oladiji, 2005), the seeds of *P. thonningii* were found to be rich in crude protein, carbohydrate, and mineral elements, also the mineral analysis of *P. thonningii* showed the seed as good source of antioxidant micronutrients such as iron, calcium, selenium, zinc and manganese.

2.3.6 Constraints of *P. thonningii* trees

P. thonningii is usually collected from the wild. For instance in Tanzania, fruits are collected in the dry season. It is sensitive to frost and liable to attack by termites and borers (Lemessa, 2010). The feeding habits of the African elephant such as bark stripping and voracious plant biomass intake are destructive and affect local plant population regeneration. The young are susceptible to annual fires. *P. thonningii* leaves decompose slowly however, the use of the leaf litter as mulch enhances soil fertility (Orwa *et al*., 2009). The seeds of *P. thonningii* are damaged by the bruchid *Caryedon serratus*, a major pest of stored groundnuts. Eggs are laid on the surface of ripe *P. thonningii* fruits, after which larvae bore through the husk and into the seed, where larval development takes

place, resulting in damaged seeds (Lemessa, 2010). Its seeds are difficult to extract because of the tough/ woody pod covering and however dormant due mainly to the hard seed-coat which is (Ayisire *et al*., 2009). The seed of *P thonningii* are damaged by bruchid *caryedon serratus* which lays eggs on the surface of ripe *P. thonningii* fruits, after which larvae bore through the husk and into the seed, where larval development takes place, resulting in damaged seeds (Lemessa, 2010). The seeds are of low yield as well as repulsive odour which limits its consumption (Jimoh and Oladiji, 2005).The seeds also have high fibre levels in diet which can cause intestinal irritation, lower digestibility and overall decreased nutrient utilization (Oyenuga and Fetuga, 1975).

2.3.7 Antinutritive factors of *P thonningii* trees

Anti-nutritional factors are a chemical compounds synthesized in plants causing different mechanisms such as inactivation of some nutrients, diminution of the digestive process or metabolic utilization of food/feed which exerts effect contrary to optimum nutrition (Soetan and Oyewole, 2009). Some antinutrients may exert beneficial health effects at low concentrations, phytate, lectins, tannins, amylase inhibitors and saponins have also been shown to reduce the blood glucose and insulin responses to starchy foods and/or the plasma cholesterol and triglycerides. Also, phytates, tannins, saponins, protease inhibitors, goetrogens and oxalates have been related to reduce cancer risks (Habtamu and Negussie, 2014).

2.3.7.1 Oxalate

Anti-nutrients, one of which is oxalate are chemicals which have been evolved by plants for their own defense, among other biological functions and reduce the maximum utilization of nutrients especially proteins, vitamins, and minerals, thus preventing optimal exploitation

of the nutrients present in a food and decreasing the nutritive value, also, under practical circumstances they can impair some aspect of animal metabolism and produce adverse biological or economic effect on animal production (Ugwu and Oranye, 2006). Oxalates are present in many plants, particularly in members of the spinach family. Oxalates binds to calcium and prevents its absorption in the human body. Many traditional method of food preparation such as fermentation, cooking and malting increase the nutritive quality of plant foods though reducing certain antinutrient such as phytic acid, polyphenols and oxalic acid (Hotz and Gibson, 2007)

2.3.7.2 Saponins

Saponins from plants have long been employed for their detergent properties. It is used as mild detergents and in intracellular histochemistry staining to allow antibody access to intracellular proteins. In medicine, it is used in hypercholesterolaemia, hyperglycaemia, antioxidant, anti-cancer, anti-inflammatory and weight loss etc, (Ngbede *et al*., 2008). (Seigler, 1998) reported that saponnins have anticarcinogens properties, immune modulatory activity and cholesterol lowering activity. it is also been reported to have anti-fungal properties (Sodipo *et al*., 1991). Some saponins glycosides are cardiotonics while others are contraceptives and precursors for other sex hormones (Evans, 2002). (Seigler, 1998) reported that saponins have anticarcinogenic properties, immune modulation activites and regulation of cell proliferation as well as health benefits such as inhibition of the growth of cancer cells and cholesterol lowering activity.Saponin in plants may serve as anti-feedants.

2.3.7.3 Flavonoids

Flavonoids are widespread form of antinutrients which are a group of polyphenolic compounds that include tannins. These compounds chelate metals such as iron and zinc and reduce the absorption of these nutrients, but they also inhibit digestive enzymes and may also precipitate proteins (Beecher, 2003). Flavonoids have been reported to play very important roles in lipid metabolism and protective functions against the incidence of lipid peroxidation and cardiovascular diseases (Tandon, 2005). Flavonoids have been reported to exert multiple biological effects including antibacterial, antiviral, antitoxic and anti-inflammatory activities (Cook and Samman, 1996).

2.3.7.4 Trypsin Inhibitor

Substances that inhibit the actions of trypsin and other proteases in the gut, preventing the digestion and subsequent absorption of protein are protease inhibitors, an example is Bowman-Birk trypsin inhibitor found in soybean (Tan-Wilson *et al*., 1987). Antinutrients are found at some level in almost all foods for a variety of reasons. However, their levels are reduced in modern crops, probably as an outcome of the process of domestication. Some proteins can also be antinutrients, such as the trypsin inhibitors and lectins found in legumes. These enzyme inhibitors interfere with digestion (Gilani *et al*., 2005).

2.4 *P. thonningii* leaves

The leaves of *P. thonningii* are conspicuously up to 15 x 17cm, bi-lobed one eighth to one third the way down with a small bristle in the notch, glossy above and heavily veined and somewhat rusty-hairy below, the stipules 3–6 mm long and deciduous while the petiole is 2–5(–7) cm long and pubescent, the blade is up to 17 cm × 21 cm and base usually strongly cordate. The apex of lobes are rounded to acute and leathery while the upper surface

glabrous, lower surface with rusty-brown crisped hairs and conspicuous reticulate venation, palmately veined with 11–15 basal veins (Lemessa, 2010).

2.4.1 Potential uses of *P. thonningii* leaves

Tender leaves are chewed and the juice swallowed to treat stomach-ache, coughs and snakebite. The ash obtained from burnt leaves is rubbed into snakebite wounds after scarification in order to hasten healing (Ruffo *et al*., 2002). An aqueous leaf extract of *P. thonningii* caused constriction of blood vessels in isolated rat aortic rings and reduced bleeding times in rats, which confirms the traditional medical application of the leaves in arresting bleeding (Ozolua *et al*., 2009). Some compounds such as Piliostigmin and three C-methylflavonols were isolated from the leaves, Some of these C-methylflavonols have been reported to contain anti-inflammatory and antibacterial activity (Ibewuike *et al.*, 1996; Ibewuike *et al*., 1997). The feeding of *P. thonningii* leaves as supplement to *Panicum maximum* enhanced digestibility of nutrients in West African Dwarf rams (Tona, 2011). The leaf decoction is a laxative and is given to children, the infusion is given to new born babies as tonic, embrocating to massage mothers abdomen and also serves as a lotion for lumbago. The leaves after soaking in hot water are applied topically for wound dressing and a leaf decoction is applied to the excision wound in the south West African region (Odukoya, 2002).

Leaf preparations are used for the treatment of diarrhoea, dysentery, worms and other intestinal problems. The leaves are boiled in water and the steam is inhaled to treat respiratory problems. Pounded leaves are rubbed on the head in case of headache (Lemessa, 2010). A leaf decoction is added to bath water against stiffness. In case of toothache, a leaf infusion or decoction is drunk or the boiled leaves are chewed. In Zimbabwe the leaves are

boiled and the strained liquid is rubbed into incisions for the treatment of painful legs (Lemessa, 2010). Leaf decoctions are drunk or used in baths or vapour baths against fever. A decoction of the leaves is used as a vaginal wash and enema to a mother giving birth. Leaf decoctions are used as a wash on fractures and the residue is massaged on the part affected. In case of bone inflammation a steam bath of the leaves boiled in water is taken. In southern Africa leaf decoctions or infusions are taken in case of heavy menstruation. Leaf sap or infusions are applied for the treatment of eye problems. In Senegal the leaves are used in the treatment of dementia (Lemessa, 2010).

2.5 *P. thonningii* pods and seeds

It is an oblong to linear-oblong pod 12–30(–37) cm × 3–7 cm, woody, brown-pubescent when young but later glabrescent (Lemessa, 2010). Pods are indehiscent up to 26 x 7 cm with rusty-brown hairs, which wear off as the pods mature, becoming somewhat contorted as they age. The pods persist on the tree but finally fall and decay on the ground to pea-sized seeds. An edible pulp surrounds these seeds (Orwa *et al*., 2009). Seeds obovoid to ellipsoid, 4–9 mm × 2–7 mm × 3–4 mm, dark brown to blackish, compressed. Seedling with epigeal germination (Lemessa, 2010).

2.5.1 Potential uses of *Piliostigma thonningii* pods and seeds

Pods and seeds have been used as source of food during famine periods. A powder can be made from the dry pods for making nutritious porridge. Unripe pods can be used as a substitute for soap. Dry pods are roasted and ground into powder, and mixed with tobacco powder and ashes of the red-leaf *Amaranthus* to make cooking soda (alternative to bicarbonate of soda) (Mutshinyalo and Sisulu, 2010). The pods are used as a soap substitute and the ashes can also be used in soap making (Orwa *et al*., 2009). The *in-vivo*

degradability of dry matter and crude protein in Holstein-Friesian steers was 33.4% and 29.8%, respectively and it was concluded that the meal could be a useful feed supplement to cattle grazing poor quality forage during the dry season (Lemessa, 2010). The high crude protein content of *P. thonningii* seed (30.33± 0.31%) (Jimoh and Oladiji, 2005) coupled with the fact that it is abundant in this part of the world may encourage its use as high protein sources in some food formulations The level of iron amongst all minerals analyzed for *P. thonningii* was found to be the highest (Jimoh and Oladiji, 2005) which might be of nutritional important in the part of the world where anaemia and iron deficiency is relatively rampant.

2.6 *P. thonningii* bark

Bark preparations have been reported to remedies against cough, colds, chest pain, pneumonia, diarrhoea, dysentery, worms and other intestinal problems, and snakebite. They are also applied on wounds, ulcers and skin infections (Lemessa, 2010). The bark is credited with pain-relieving activity, and is used for the treatment of sore throat, toothache, gum problems, earache, stomach-ache and general body pain. Bark decoctions are rubbed in or used as a vapour bath for the treatment of rheumatism, muscular pain and bone inflammation. They are also taken as an antiemetic. Infusions of the bark are taken for the treatment of internal abscesses and haematuria, and infusions of the bark and leaf are used against malaria. In East Africa bark sap, or the bark boiled in milk or in soup, is drunk for the treatment of gonorrhoea. In Gambia sap from the bark is used to induce dizziness in dancers (Lemessa, 2010).

2.7 *P. thonningii* roots

P. thonningii is widely used in African traditional medicine. Root preparations are applied on wounds and ulcers as a haemostatic and to promote healing. They are also used as a diuretic and for the treatment of diarrhoea, dysentery, worms and other intestinal problems. Cough remedies are prepared from the root as well (Neuwinger, 2000). Various root preparations are taken or applied in case of snake bites, and in DR Congo roots serve as antidote to poisonous plants (Neuwinger, 2000). In DR Congo and Malawi the roots are used to treat rheumatism. The root heated in fat is used as a poultice in case of a painful spleen. Root decoctions are drunk to prevent miscarriage. Root decoctions or infusions are taken in case of heavy menstruation and a painful uterus, and given to a mother that has given birth. Root infusions are taken to promote conception and against venereal diseases. They are used in baths against vertigo. In Uganda the root is smoked against insanity, and in Zimbabwe the powdered root is eaten against convulsions (Neuwinger, 2000). Root fibres are made into rope and roots serve as toothbrushes. The root yields a red-brown or black dye. In Ghana, Nigeria and DR Congo women chew the root-bark to redden their lips and the bark is also rubbed on the lips to colour these red (Lemessa, 2010).

2.8 Method of processing *P. thonningii* product

The common adopted method for processing *P. thonningii* product such as the leaf due to less work being carried on the plant is air drying or shade drying after which it is milled or pound into powdery form. Tona (2011) enhanced the digestibility of West African Dwarf Rams fed wilted leaves of *P. thonningii* and *Panicum maximum*. Also, leaf extract obtained after the leaf is shade dried and coarsely powdered revealed anti-ulcer potential of the

ethanol extract of the leaf of *P. thonningii* against *in vivo* indomethacin- induced gastric ulcer using pylorus ligation method (Venkateshwarlu *et al*., 2011).

2.9 The rumen ecosystem

The rumen is found on the left side of the animal, it is the largest of four compartments. Because of its size, the rumen acts as a storage or holding vat for feed. Tiny projections called papillae increase the surface area and the absorption capacity of the rumen (Gressley *et al*., 2011). Ruminants digestive fermentation results in fermentation end-products of volatile fatty acids (VFA), microbial protein and methane production in the rumen. Rumen microorganisms including bacteria, protozoa and fungal zoospores are closely associated with the rumen fermentation efficiency (Wanapat *et al*., 2015). Conditions within the rumen favour the growth of microbes. The rumen absorbs most of the volatile fatty acids produced from fermentation of feedstuffs by rumen microbes. Absorption of volatile fatty acids and some other products of digestion are enhanced by a good blood supply to the walls of the rumen (Gressley *et al*., 2011).Short chain fatty acid, SCFA is the principal element involved in forming the rumen osmotic pressure. Both the osmolarity and the pH directly influence the microbial composition. Therefore, the stability of the SCFAs concentrations and their molar proportions are essential for a healthy rumen ecosystem and a healthy animal (Pacheco *et al*., 2012).

2.9.1 Rumen pH

The pH of the rumen undergoes diurnal flunctuations and reflects the balance of acid production and absorption as well as the buffering function provided by bicarbonates in the saliva (Van Soest, 1994).Volatile fatty acid (VFA) production increase after feeding resulting in a depression in rumen pH but as the rate of VFA production decreases and

absorption continues in the hours between feeding, the rumen pH will rise again. The rumen pH of ruminant fed predominantly forage diet is generally higher in the range of 6.2 to7 than those fed diets with larger proportion of concentrates with rumen pH ranging from 5.5 to 6.5 (Kolver and de Venth, 2002). Because plant cell walls are slow to digest, this acid production is very slow. Coupled with routine rumination that increases salivary flow, this makes for a rather stable pH environment (around 6.0) (MSU, 2009). Saliva is the major buffer for helping to maintain a rumen pH between 6.2 and 6.8 for optimum digestion of forages and feedstuffs. Feeding large quantities of unsaturated fatty acids can be toxic to rumen bacteria, depress fiber digestion, and lower rumen pH (UMN, 2017).

2.9.2 Rumen digestion

On high-forage diets ruminants often ruminate or regurgitate ingested forage. Once inside the reticulorumen, forage is exposed to a unique population of microbes that begin to ferment and digest the plant cell wall components and break these components down into carbohydrates and sugars. Rumen microbes use carbohydrates along with ammonia and amino acids to grow. The microbes ferment sugars to produce VFAs (acetate, propionate, butyrate), methane, hydrogen sulphide, and carbon dioxide. The VFAs are then absorbed across the rumen wall, where they go to the liver, the VFAs are converted to glucose via gluconeogenesis (MSU, 2009).

On a high-grain diet, there is less chewing and ruminating, which leads to less salivary production and buffering agents being produced. Most grains have a high concentration of readily digestible carbohydrates, unlike the more structural carbohydrates found in plant cell walls. This readily digestible carbohydrate is rapidly digested, resulting in an increase in VFA production. The relative concentrations of the VFAs are also changed, with

propionate being produced in the greatest quantity, followed by acetate and butyrate. Less methane and heat are produced as well. The increase in VFA production leads to a more acidic environment (pH 5.5). It also causes a shift in the microbial population (MSU, 2009). Two sources of protein are available for the ruminant to use: protein from feed and microbial protein from the microbes that inhabit its rumen. All crude protein (CP) the animal ingests is divided into two fractions, degradable intake protein (DIP) and undegradable intake protein (UIP). Rumen microbes break down the DIP into ammonia (NH_3) amino acids, and peptides, which are used by the microbes along with energy from carbohydrate digestion for growth and reproduction. Excess ammonia is absorbed via the rumen wall and converted into urea in the liver. The UIP "bypasses" the rumen and makes its way from the omasum to the abomasum. In the abomasum, the ruminant uses UIP along with microorganisms washed out of the rumen as a protein source (MSU, 2009). The rumen micro-organisms manufacture all of the B vitamins and vitamin K. Vitamin synthesis in the rumen is sufficient for growth and maintenance. Rumen micro-organisms change unsaturated fatty acids to saturated acids through the addition of hydrogen molecules (UMN, 2017).

2.9.3 Volatile fatty acids production

In the rumen, approximately 60%–70% of the ingested feed is fermented by microbes to produce volatile fatty acids which are short chain fatty acids (SCFAs). The major SCFAs are acetate, propionate, and butyrate. They supply approximately 50%–70% of the energy needs of the animals (Bergman, 1990). Acetate is utilized by adipose tissue (Britton and Krehbiel, 1993). Propionate is the main substrate or precursor for gluconeogenesis in the liver. The liver produces 60%–70% of the body's glucose via gluconeogenesis (Annison *et*

al., 2002). Butyrate is the most preferred fuel utilized by digestive epithelial cells, providing energy for their metabolic and immune activities (Muller *et al*., 2002). In the ruminal microbiota, the function and the expression of the genes involved in metabolism and virulence are affected by the SCFAs concentration (Pacheco *et al*., 2012).

2.9.4 Methane production

In the case of ruminants, much of the gas (wind) expelled is produced as a by-product of the animal's digestive process. These gasses notably include a large volume of methane, produced exclusively by a narrow cohort of methanogenic archaea in the animal's gut; *Escherichia coli* (*E. coli*) and other bacteria lack the enzymes and cofactors required for methane production. A small amount of methane is also produced by their manure. Cows are thought to emit an average of 542 litres (if located in a barn) and 600 litres (if in a field) of methane per day through burping and exhalation, making commercially farmed cow a major contributor to the greenhouse effect . Methane is a by-product of fermentation in the rumen and is expelled by belching or eructation. Around 80% of ruminant methane emissions emerge from the mouth of the animal, with only 20% emitted from the rear (Verge *et al*., 2007).

2.10 Green house gases

Global warming, the rise in the average surface temperature of the earth has been attributed to greenhouse gases (GHGs) like carbon dioxide (CO_2), methane (CH_4), water vapour (H_2O), nitrous oxide (N_2O) and hydroflurocarbons (HFCs) through the "greenhouse effect" which is an alarming issue worldwide (Smit *et al*., 2014; Li *et al*., 2016). Carbon dioxide (CO_2) contributed 77%, CH_4 14%, N_2O 8%, and HFCs 1% of global GHG emissions (IPCC, 2007). The current concentrations of CO_2, CH_4, and N_2O are 395.4 ppm, 1893 ppb,

and 326 ppb respectively, having a lifetime of 100–300, 12, and 121 years, respectively. The intensity of warming for each gas is referred to as the Global Warming Potential (GWP). The GWP of CH_4, N_2O, and hydroflurocarbons (HCFs) are 23, 296, and 12000 respectively (Jose *et al*., 2016). The increasing atmospheric concentrations of GHGs in recent years are primarily due to the anthropogenic activities involving fossil fuel burning, application of nitrogen fertilizers in farming and the rearing and breeding of ruminants. In actuality GHG's are necessary for human survival. Over millennium GHGs have stabilized in the atmosphere resulting in an average surface temperature of 15°C. Without the heat retention capacity of GHG the Earth would likely be uninhabitable. Natural processes are also contributing to increasing levels of atmospheric GHG; however, the aforementioned anthropogenic activities are now contributing to additional warming, leading to rapid climate change (IPCC, 2013; Quaghebeur *et al*., 2015).

2.10.1 Greenhouse gas emission

In livestock production: The livestock sector is considered to be a major contributor to climatic change. The sources of GHG from livestock production systems were determined to be from land use and land change, feed production, animal production, manure management, and processing and transportation. It has been estimated that approximately 12.5% of the total global GHG emission are from the livestock sector (Jose *et al.*, 2016) and 80% of the total emission from agriculture is from the livestock sector. Approximately 9% of CO_2, 36% of CH_4, and 64% of N_2O contributed to the livestock production process and 75% of the CO_2 emitted from livestock is from ruminants (Prasad *et al*., 2015)

In industries and others: green house gases are naturally occurring, but the increasing concentration due to the anthropogenic effects is of concern. GHG emissions have been

determined for the industrial or agricultural sector. Energy generation contributes 26% of total global emissions, industries 19%, land use, land change and forestry 17%, agriculture 14%, residential and commercial buildings 8%, and waste and wastewater contribute 3% (IPCC, 2007).

2.10.2 Effect of greenhouse gases

It is clear that climate change is real and that the forces behind this change are greenhouse gases emissions (Jose *et al*., 2016) .Methane emission from the ruminant livestock sector, a by-product from enteric fermentation of plant biomass in the ruminant digestive system is produced by methanogenic archaea and represents not only a significant amount of anthropogenic greenhouse gases contributing to climate change but also an energy loss and a reduction in feed efficacy (Evert *et al*.,2016). According to the (IPCC, 2013), over the period 1880–2012 the average land and ocean temperature increased by 0.85°C (0.65 to 1.06°C), and the last three decades were warmer than any other decade before 1850, increasing temperature has resulted in the melting of glaciers and Arctic sea ice.

2.10.3 Methane as one of the main green house gases

Globally, it has been estimated that livestock account for 15% of total GHG emissions (Steinfeld *et al.*, 2006), so there is a great deal of interest in finding ways to reduce this value. The global warming potential of methane is about 25 times that of carbon dioxide (Forster *et al.*, 2007), so a small reduction in methane production could have significantly beneficial effects. Recently, researchers in a number of countries have shown that it is possible to reduce methane emission from ruminant animals by altering their diet, but this is only likely to have a beneficial effect on GHG emissions if the necessary feeds are

available to farmers at a cost that does not increase the overall cost of the diet, and if these feeds do not have a negative effect on animal production.

Enteric fermentation causes the emission of CH_4, which is a by-product of the breaking down of carbohydrate molecules into soluble particles by methanogens residing within the rumen. Thus, formed CH_4 is eructated by the animal and becomes a greenhouse gases (GHG). Feed quality is a major determinant of CH_4 production. High fibre content (cellulose) in the feed will increase CH_4 emission (Jose *et al*., 2016). On a global scale, agriculture and in particular enteric fermentation in ruminants is reported to produce about one fourth (21 to 25%) of the total anthropogenic emissions of methane (CH4) (Raghavendra and Osamu, 2007). The current concentrations of CO_2, CH_4, and N_2O are 395.4 ppm, 1893 ppb, and 326 ppb respectively, having a lifetime of 100–300, 12, and 121 years, respectively (Le Quéré *et al*., 2014; Beyzavi *et al*., 2015).

2.10.4 Mitigation of greenhouse gas emission

2.10.4.1 Modification of rumen environment

Removal of protozoa (defaunation) with sodium 1-(2-sulfonatooxyethoxy) dodecane (Empicol) administered at 45 g/d in a 10% v/v solution which give rise to the absence of protozoa reduced CH_4 production by 16% (Nguyen *et al*., 2015) . The study of Nguyen *et al*., 2015 indicated that the combined effects of protozoal treatment and dietary NO_3 led to more than additive reduction in CH_4 production (19.11 mL) compared with the sum of the protozoal effect (3.52 mL) and the dietary NO_3 effect (9.38 mL). Hence, the combined effects of NO_3 and defaunation reduced CH_4 production by 86%.

Scientists demonstrated the effectiveness of 3-nitrooxypropanol(3NOP) in reducing methane production using incubated anaerobic microorganisms from ruminants digestive

systems which revealed how 3NOP only affected the methane-producing microorganisms and not those that contribute to digestion. This points to a reduction in the production of methane without adverse effects on the animal's health, production or welfare hence contributing to a reduction in global temperatures that are influenced by greenhouse gases. Therefore a better use is made of the energy taken-in in animal feed, given that methane production accounts for a loss of up to 12 percent of the energy an animal ingests (CSIC, 2016 and Evert *et al*., 2016). In 2015, Hristov and others in PNAS (Proceedings of the National Academy of Sciences) found that 3NOP, applied at 40 to 80mg/kg feed dry matter, decreased methane emissions from high-producing dairy cows by 30 percent and increased body weight gain, without negatively affecting feed intake or milk production and composition.

2.10.4.2 Dietary strategies

Fat concentrations of up to 6% of diet DM (dry matter) may also increase milk production and lower enteric methane (CH_4) emissions appreciably (15%) in cattle (Patra, 2013). Among fatty acids, C12:0, C18:3 and poly unsaturated fatty acids have more marked CH_4 suppressing effects. The feeding of red grape marc to dairy cows decreased CH_4 emissions and CH_4 yield by 20% (Moate *et al*., 2014). Dietary nitrate (NO_3) has been shown to offer a reliable and predictable strategy to mitigate CH_4 production from ruminants in both *in vitro* and *in vivo* studies. In addition, NO_3 reduced total gas production, total VFA concentrations and the proportion of butyrate *in vitro*. Also, dietary NO_3 reduced CH_4 production by 42% according to Nguyen *et al*., 2015.

Halogenated compounds had been investigated as inhibitors of CH_4 production in the rumen over 40 years ago (Patra, 2012; Patra, 2016). Some marine plants, such as the red

seaweed, algae, and fungi, contain bromoform and other halogenated compounds at high concentrations (Patra, 2016) which have been exploited recently to inhibit CH_4 production. In a recent *in vitro* experiment, red seaweed, *Asparagopsis taxiformis*, was shown to reduce CH_4 production by 99% when it was used at 2% of organic matter substrate (Machado *et al*., 2014). In another study in sheep fed Monascus-fermented rice, CH_4 emission was decreased by 30% by fungal metabolites (possibly pravastatin and mevastatin) produced by *Monascus* spp., which was associated with lower ruminal acetate to propionate ratio and decreased numbers of methanogens in the rumen (Morgavi *et al*., 2013). Machado *et al*., 2014 screened several marine microalgae *in vitro* and reported that *Asparagopsis* not only strongly decreased CH_4 production by 99% at a dose of as low as 2% of total substrate organic matter, but also decreased the production of VFA.

2.10.4.3 Plant secondary compound

Several plant secondary metabolites present in forages and plant extracts have been identified to be potential for CH_4 inhibition in the rumen (Patra and Saxena, 2010). Many forage plants rich in tannins and saponins have shown to be promising to reduce CH_4 production in ruminants (Li *et al*., 2014; Pal *et al*., 2015). swedes and forage rape significantly decreased CH_4 yield by 20%(Sun *et al*., 2012). A recent study reported that inclusion of flavone, myricetin, naringin, rutin, quercetin, and kaempferol significantly decreased *in vitro* CH_4 production from 8.6 to 5.7, 4.9, 6.3, 7.2, 6.2, and 5.3 mL/g DM, respectively. The inhibitory activities of flavonoids used in this experiment toward methanogenesis were in the following descending order as follows: myricetin ≥ kaempferol ≥ flavone > quercetin ≥ naringin > rutin ≥ produchin (Oskoueian *et al*., 2013).

In a study, a binary combination of nitrate and quillaja saponin inhibited methanogenesis additively in an *in vitro* rumen culture [by 32% at 5 mM nitrate and 0.6 g/L saponins, and by 58% at 10 mM nitrate and 1.2 g/L saponins] (Patra and Yu, 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The experiment was carried out at the Department of Animal Science Teaching and Research Farm, Ahmadu Bello University, Zaria. Zaria is within the Northern Guinea savannah zone of Nigeria, latitude 11^0 04'N, longitude 7^0 42'E and on altitude of 706m above sea level (Wikipedia, 2015). The climate is relatively dry with an average annual rainfall of 1100mm, the annual temperature does not exceed 35^0C. The ambient temperature rarely falls below 26^0C except during the harmattan period when temperature below 26^0C may be recorded; weather report, Institute of Agricultural Research, Samaru (IAR, 2016).

3.2 Sources and Processing of *Piliostigma thonningii* Fresh Leaves and Pods

Piliostigma thonningii fresh leaves and pods were acquired from Minjibir town in Kano State. The leaves and the pods were shade dried for 10 days and were milled using hammer mill fitted with 1.5mm sieve. The *P. thonningii* leaf and pod meals were packed in polythene bags and kept in a dry place until required for feed formulation. Four complete diets containing graded levels of *P. thonningii* leaf and pod meals at 0, 5, 10 and 15% inclusion levels were formulated with other feed ingredients (Table 3.2a and b).

3.3 Management of Experimental Animals and Design

Eight Yankasa lamb rams aged 6-9 months were used for each study, of which four lamb rams with body weight 17-19kg were used for experiment 1 and the other four lamb rams with 22-24kg body weight was used for experiment 2, in a 4x4 Latin Square Design (Table

3.1). The lamb rams were purchased from a local market within Zaria. The animals were given prophylactic treatment against ecto and endo parasites using Ivomec® (Ivermecin injection at the rate of 0.1ml/50kg body weight) on arrival and also tetracycline Long Acting (TLA) injection was administered according to manufacturer's recommendation to prevent the attack of other disease pathogen. The lamb rams were adjusted 2 weeks before the commencement of the study. Four complete diets containing graded levels of *P. thonningii* leaf and pod meals at 0, 5, 10 and 15% inclusion levels formulated with other feed ingredients graded levels diet were rotated among the animals for four periods with each periods having a duration of 14 days collection period and 7 days adjustment of the lamb rams to the diets in between the periods. The diets were fed to the lamb rams at 4% of their body weight for a period of 3 months for each experiment. The body weights of the lamb rams were taken at the beginning and end of each period to adjust for the level of feed based on body weight. Water and mineral salt lick were provided ad libitum.

3.4 Data Collection

The lamb rams were weighed at the beginning of the experiment and fortnightly thereafter throughout the 90days period of the experiment. The fortnight weight was used to adjust the quantity of feed offered. Leftover feed from concentrate diets were weighed and recorded separately each morning before feeding. The animals were fed 8:00 a.m in the morning and 12:00 pm in afternoon. Feed intake was recorded by measuring the amount of feed offered and then subtracting the left over recorded the next day from it. Water intake was recorded by measuring the amount of water offered and then subtracting the left over recorded the next day from it. Evaporative loss was monitored by maintaining similar water trough throughout the experiment.

3.5 Nutrient Digestibility and Nitrogen Retention Study

Four (4) lamb rams were used for digestibility and N-balance study. The animals were individually kept in metabolic cages having provision for quantitative collection of faeces and urine as described by (Osuji *et al.*, 1993). The lamb rams were maintained on the same diets used in the feeding trial. The initial 7days was used to adjust the lamb rams to the digestibility crates and the latter 7days for collection of samples (faeces and urine). Each morning (8:00am), feed refused, total faecal and urine outputs were collected from each animal, weighed, bulked and sub-sampled for analysis. About 10g of faeces were collected and oven dried to constant weight for the dry matter determination. While 20% formaldehyde was added to the remaining faecal sample and stored in deep freezer pending laboratory analysis. At the end of the collection period, the faecal samples were bulked and sub-samples were collected for laboratory analysis. Total urine outputs were also collected daily in plastic bottles containing 10ml of 0.1N H_2SO_4 to prevent nitrogen loss by volatilization in the urine. The daily urine collected were bulked and 10% of the bulked urine output were sub sampled for each lamb rams and stored in a deep freezer until required for nitrogen determination.

Table 3.1 Experimental layout in a 4X4 Latin square design

Period	Ram1	Ram2	Ram3	Ram4
1	T1	T2	T3	T4
2	T2	T3	T4	T1
3	T3	T4	T1	T2
4	T4	T1	T2	T3

Table 3.2a: Gross composition of experimental diets containing varying levels of *P. thonningii* leaf meal (PTLM)

Ingredient	Inclusion level of PTLM (%)			
	0	5	10	15
Maize offal	45.00	41.25	37.50	33.75
Cotton seed cake	25.00	23.75	22.50	21.25
P. thonningii leaf meal	-	5.00	10.00	15.00
Rice offal	27.00	27.00	27.00	27.00
Bone meal	2.00	2.00	2.00	2.00
Common Salt	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Crude protein (%)	13.93	13.90	13.89	13.91
Crude fibre (%)	17.57	17.77	17.86	17.48
ME (Kcal/Kg Diet)	2787	2788	2793	2796
Cost/Kg diet (₦)	47.35	44.38	41.13	38.44

Table 3.2b: Gross composition of experimental diets containing varying levels of *P. thonningii* pod meal (PTPM)

Ingredient	Inclusion level of PTPM (%)			
	0	**5**	**10**	**15**
Maize offal	45.00	41.25	37.50	33.75
Cotton seed cake	25.00	23.75	22.50	21.25
P. thonningii Pod meal	-	5.00	10.00	15.00
Rice offal	27.00	27.00	27.00	27.00
Bone meal	2.00	2.00	2.00	2.00
Common Salt	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00
Calculated Analysis				
Crude protein (%)	13.55	13.60	13.57	13.64
Crude fibre (%)	19.94	19.92	19.90	19.89
ME (Kcal/Kg Diet)	2920	2898	2899	2900
Cost/Kg diet (₦)	43.11	38.22	32.17	27.03

3.6 Measurement of Rumen Metabolites

Rumen fluid samples were collected from four lamb rams by aspiring method using stomach tube at the end of the digestibility trial at 0, 3 and 6hrs post feeding, for the determination of rumen fluid pH, total volatile fatty acids (TVFAs) and rumen ammonia nitrogen (NH_3-N) concentration. The pH of the rumen fluid was recorded immediately using a digital pH meter. The fluid was then strained through a cheese cloth. About 30mls of the filtrate were collected and mixed with an equal volume of 0.1N H_2SO_4 saturated with $MgSO_4$ in plastic containers to acidify; de-protenize and lower bacterial activity as described by (Briggs *et al.*, 1957). The mixture was centrifuged at 3000rpm for 10 minutes. Thereafter, about 20mls of the supernatant were decanted into plastic bottles and stored in deep freezer (1-20^oC) until required for analysis.

3.7 Laboratory Analysis

Samples of *Piliostigma thonningii* pods and leaf meals, experimental diets and faecal samples were analyzed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), ash and nitrogen free extract (NFE), according to the method (AOAC, 2005). The fibre fractions, Acid Detergent Fibre (ADF) and Neutral Detergent Fibre (NDF) were determined according to the method described by (Goering and Van Soest, 1970). Urine samples were analyzed for nitrogen using the macro-Kjeldahl distillation method (AOAC, 2005).

Metabolizable energy of the diets was estimated using the equation of (Alderman, 1985):

$$\mathbf{ME\ (MJ/Kg\ DM) = 11.78+0.00654CP+(0.000665EE)^2 - CF(0.00414EE) - 0.0118A}$$

Where: A = Ash content, CP = Crude protein, EE = Ether extract, CF = Crude fibre.

3.8 Estimation of Methane Emission from Yankasa Rams using models

Although calculating the exact amount of green house gases emitted by ruminant livestock requires the use of sophisticated tools, which are practically unavailable in Nigeria. In this study, the methane emitted by Yankasa lamb rams were estimated through the use of some models designed for ruminant livestock. These models involves the use of some equations, results from the live weight, dry matter intake and digestible nutrients in Yankasa lamb rams fed experimental diets were used. The equation for the models are as follows;

$Model_1$: Methane (KJ/d) = 1.62 × DCP – 0.38 × DCFAT + 3.78 × DCF + 1.49 × DNFE + 1142 (g/d) (Jentsch *et al.*, 2007);

$Model_2$: Methane (L/d) = 47.8 × DMI – 0.76 × DMI^2 – 41 (kg/d) (Yan *et al.*, 2007);

$Model_3$: Methane (L/d) = 0.34 × BW (Kg) + 19.7 × DMI (Kg/d) + 12 (Ida *et al.*, 2012).

Where:

DMI - Dry matter intake,

DCP - Digestible crude protein,

DCFAT - Digestible crude fat,

DCF - Digestible crude fibre,

DNFE - Digestible nitrogen free extract,

BW - Body weight.

3.9 Cost Benefit Analysis

Cost benefit analysis was carried out to determine the profitability of including *P. thonningii* leaf and pod meals in the concentrate diets of Yankasa rams. Costs of *P. thonningii* leaf and pod meals was estimated from the total expenditure used in the

production process. Costs of other inputs were based on feed cost per kilogram at the prevailing market prices of the commodities.

3.10 Statistical Analysis

Data generated from the two experiments were analyzed using the General Linear Model (GLM) Procedure of SAS (2001) Software for analysis of variance. Significantly different means were compared using Duncan's Multiple Range Test. The Mathematical Model used is indicated below:

$$\mathbf{Y_{ijk} = \mu + P_i + R_j + T_{k +} e_{ijk}}$$

Where:

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

μ = Overall mean

P_i = Effect of period of time

R_j = Effect of the j^{th} ram

T_k =Effect of the k^{th} treatment diet (k = Inclusion level of *P. thonningii* leaf and pod meal)

e_{ijk} = Random error.

CHAPTER FOUR

4.0 RESULTS

4.1 Proximate composition and anti nutritional content in *P. thonningii* leaf meal (PTLM) and *P. thonningii* pod meal (PTPM).

The results obtained from the proximate composition PTLM and PTPM are presented in Table 4.1. PTLM had a dry matter (DM) content of 93.93%, organic matter (OM) content of 88.57%, crude protein (CP) content of 14.13%, crude fibre (CF) content of 8.28%, ether extract (EE) of 3.78%, ash content of 5.36% and nitrogen free extract (NFE) of 68.45%, while PTPM had DM content of 94.12%, OM of 89.11%, CP content of 12.44%, CF of 9.56%, EE4.19%, ash content of 5.01% and NFE of 68.80%.

The results obtained from the anti nutritional content PTLM and PTPM (Table 4.1) revealed that PTLM had saponin content of 1.28mg, flavonoid (0.88mg), oxalate (2.53mg) and trypsin inhibitor (1.68mg), while PTPM had saponin content of 2.50mg, flavonoid (1.86mg), oxalate (3.84mg), trypsin inhibitor (3.96mg).

4.2 Chemical composition of the experimental diet

The results obtained from the chemical composition of the experimental diets are presented in Table 4.2. The chemical composition of the experimental diet (PTLM inclusions at 0, 5, 10 and 15%) respectively, had DM contents of 95.81, 95.39, 95.37 and 95.14 %, OM (90.09, 89.55, 90.55 and 91.36%), CP (14.81, 13.75, 14.38 and 12.81%), CF (16.00, 13.46, 13.25 and 12.66%), EE (8.10, 7.40, 7.00 and 6.90%), NFE (45.37, 51.24, 23.29 and 33.27%), Ash content (9.86, 10.45, 9.45 and 8.64%), Metabolisable energy (ME) (11.22, 11.33, 11.38 and 11.40 MJ/kgDM), Neutral detergent fibre (NDF) (34.11, 33.47, 31.07 and

35.68%) Acid detergent fibre (ADF) (21.02, 22.68, 23.81 and 20.83%), and Hemicelluloses (13.09, 10.79, 8.26 and 14.85%) respectively.

The chemical composition of the experimental diet (PTPM inclusions at 0, 5, 10 and 15%) respectively had DM content of 95.81, 95.40, 95.37 and 95.14%, OM (90.09, 90.05, 90.55 and 91.36%), CP (14.81, 16.94, 13.38, 13.25%), CF (16.00, 13.60, 12.21 and 10.39%), EE (8.10, 7.90, 7.52 and 7.30%), NFE (45.37, 47.43, 52.81 and 55.83%), Ash (9.86, 9.95, 10.08 and 10.43%), ME (11.22, 11.33, 11.37 and 11.43MJ/kgDM), NDF (34.11, 33.76, 33.99 and 38.23%), ADF (21.02, 21.24, 22.31 and 23.36%), and Hemicelluloses (13.09, 11.52, 11.68, 14.87%) .

Table 4.1: Proximate composition and anti-nutritional contents in *Piliostigma thonningii* leaf and pod meals

Parameter	Leaf meal	Pod meal
Proximate composition (%)		
Dry matter	93.93	94.12
Organic matter	88.57	89.11
Crude protein	14.13	12.44
Crude fibre	8.28	9.56
Ether extract	3.78	4.19
Ash	5.36	5.01
Nitrogen free extract	68.45	68.80
Anti- nutritional contents (mg)		
Saponin	1.28	2.50
Flavonoids	0.88	1.86
Oxalate	2.53	3.84
Trypsin inhibitor	1.68	3.96

Table 4.2: Chemical composition of the experimental diet containing varying inclusion levels of PTLM and PTPM

	Inclusion levels (%)							
	0		5		10		15	
Parameters (%)	**PTLM**	**PTPM**	**PTLM**	**PTPM**	**PTLM**	**PTPM**	**PTLM**	**PTPM**
Dry matter	95.81	95.81	95.39	95.40	95.37	95.37	95.14	95.14
Organic matter	90.09	90.09	89.55	90.05	90.55	90.55	91.36	91.36
Crude protein	14.81	14.81	13.75	16.94	14.38	13.38	12.81	13.25
Crude fibre	16.00	16.00	13.46	13.60	13 .25	12.21	12.66	10.39
Ether extract	8.10	8.10	7.40	7.90	7.00	7.52	6.90	7.30
NFE	45.37	45.37	51.24	47.43	23.29	52.81	33.27	55.83
Ash	9.86	9.86	10.45	9.95	9.45	10.08	8.64	10.43
ME (MJ/KgDM)	11.22	11.22	11.33	11.33	11.38	11.37	11.40	11.43
NDF	34.11	34.11	33.47	33.76	31.07	33.99	35.68	38.23
ADF	21.02	21.02	22.68	21.24	23.81	22.31	20.83	23.36
Hemicellulose	13.09	13.09	10.79	11.52	8.26	11.68	14.85	14.87

PTLM – *Piliostigma thonningii* leaf meal, PTPM – *Piliostigma thonningii* pod meal, NFE – Nitrogen free extract, ME – Metabolisabe energy, NDF – Neutral detergent fibre, ADF – Acid detergent fibre

4.3 Growth Performance of Yankasa rams

4.3.1 Growth performance of Yankasa lamb rams fed diets containing PTLM inclusions

The result obtained from the growth performance of Yankasa lamb rams fed varying inclusion levels of PTLM is presented in Table 4.3.1. The result showed that there was no significant ($P>0.05$) difference in the feed intake (average daily feed intake (ADFI) and total feed intake (TFI)) of Yankasa lamb rams across the dietary treatments, also, there was no significant ($P>0.05$) difference in the water intake (daily water intake (DWI) and total water intake (TWI)) across the dietary treatments. The feed conversion ratio (FCR) of Yankasa lamb rams fed diet containing PTLM inclusions was significant ($P<0.05$), FCR was best among animals fed 5% inclusion level of PTLM, animals fed 5 and 0% PTLM inclusions had significantly ($P<0.05$) similar FCR but significantly ($P<0.05$) different and higher than those fed 15 and 10% inclusion levels. There was no significant ($P>0.05$) difference in the weight (initial and final weight) of Yankasa lamb rams fed PTLM inclusions across the dietary treatments. The weight gained (average daily weight gain (ADWG) and average weight gain (AWG)) by Yankasa lamb rams was significanlty ($P<0.05$) affected by PTLM inclusions, animals fed 5% inclusion level of PTLM had significantly ($P<0.05$) different and higher ADWG compared to other dietary treatment while the ADWG of those fed 0 and 15% inclusions were significantly ($P<0.05$) similar but significantly ($P<0.05$) higher than animals fed 10% PTLM inclusion, also animals fed 5% PTLM inclusion had significantly ($P<0.05$) higher AWG than those fed 0, 15 and 10% PTLM inclusion levels which were significantly ($P<0.05$) similar.

4.3.2 Growth performance of Yankasa rams fed diets containing PTPM inclusions

The result obtained from the growth performance of Yankasa lamb rams fed varying inclusion levels of PTPM is presented in Table 4.3.2. The result showed that there was no significant ($P>0.05$) difference in the feed intake (average daily feed intake (ADFI) and total feed intake (TFI)) of Yankasa lamb rams across the dietary treatments, also, there was no significant ($P>0.05$) difference in the water intake (daily water intake (DWI) and total water intake (TWI)) across the dietary treatments. The feed conversion ratio (FCR) of Yankasa lamb rams fed diet containing PTPM inclusions was significant ($P<0.05$), FCR was best among animals fed 5% inclusion level of PTPM, animals fed 5% PTPM inclusion had significantly ($P<0.05$) higher FCR when compared with those fed 0, 15 and 10% inclusion levels of PTPM which were significantly ($P<0.05$) similar. There was no significant ($P>0.05$) difference in the weight (initial and final weight) of Yankasa lamb rams fed PTPM inclusions across the dietary treatments. There was significant ($P<0.05$) difference in the weight gained (ADWG and AWG) by Yankasa lamb rams fed PTPM inclusions, animals fed 5, 0 and 15% PTPM inclusions had significantly ($P<0.05$) similar and higher ADWG than those fed 10% PTPM inclusion while the AWG followed similar pattern.

Table 4.3.1: Growth performance of Yankasa rams fed diets containing varying levels of PTLM

Parameter	Inclusion level of PTLM (%)				SEM
	0	5	10	15	
ADFI (g)	915.66	951.82	987.05	978.91	58.05^{NS}
Total Feed Intake (kg)	12.82	13.33	13.82	13.71	0.81^{NS}
DWI (l/d)	2.09	1.99	2.03	2.26	0.28^{NS}
Total Water Intake (l/d)	29.24	27.88	28.39	31.64	3.93^{NS}
Feed Conversion Ratio	6.96^{ab}	5.79^{a}	8.61^{c}	7.57^{bc}	0.67*
Initial weight (kg)	20.63	20.38	20.63	20.63	1.37^{NS}
Final weight (kg)	22.50	22.75	22.25	22.50	1.40^{NS}
ADWG (g/day)	133.93^{b}	169.64^{a}	116.07^{c}	133.93^{b}	15.46*
AWG (kg)	1.87^{b}	2.37^{a}	1.62^{b}	1.87^{b}	0.22*

[a, b, c,] Means within row with different superscripts are significantly different ($p<0.05$), SEM= Standard Error of Means, AWG Average weight gain, ADWG = Average Daily Weight Gain, ADFI= Average daily feed intake, FCR= Feed conversion ratio, DWI = Daily water intake, TWI = Total water intake.

Table 4.3.2: Growth performance of Yankasa lamb rams fed diets containing PTPM inclusions

Parameter	Inclusion level of PTPM (%)				SEM
	0	5	10	15	
ADFI (g)	1401.00	1379.80	1394.50	13 98.10	167.64^{NS}
TFI (kg)	19.61	19.32	19.52	19.73	2.36^{NS}
DWI (l/day)	2.01	1.86	1.73	1.90	0.17^{NS}
TWI (l/day)	28.17	26.02	24.25	26.56	2.36^{NS}
FCR	8.30^{b}	7.50^{a}	9.76^{b}	8.35^{b}	1.00*
Initial weight (kg)	26.13	25.75	26.50	26.63	1.80^{NS}
Final weight (kg)	28.63	28.38	28.50	29.00	1.89^{NS}
ADWG (g/day)	178.57^{a}	187.50^{a}	142.86^{b}	169.64^{a}	20.29*
AWG (kg)	2.50^{ab}	2.63^{a}	2.00^{b}	2.37^{ab}	0.28*

[a, b] Means within row with different superscripts are significantly different ($p<0.05$), SEM= Standard Error of Means, AWG = Average weight gain, ADWG = Average Daily Weight Gain, TFI = Total feed intake, ADFI= Average daily feed intake, FCR= Feed conversion ratio, DWI = Daily water intake, TWI = Total water intake.

4.4 Nutrient digestibility of Experimental diets fed to Yankasa lamb rams

4.4.1 Nutrient digestibility of diets containing varying levels of PTLM

The result from the nutrient digestibility of diets containing inclusion levels of PTLM by Yankasa lamb rams is presented in Table 4.4.1. There was no significant ($P>0.05$) difference in the dry matter (DM) digestibility across the dietary treatments. The organic matter and crude protein digestibility was not significantly ($P>0.05$) affected by PTLM across the dietary treatments. The digestibility of crude fibre (CF) was significantly ($P<0.05$) affected by dietary treatments, animals fed diets containing 10 and 15% PTLM with values 73.06 and 69.51%, respectively had significantly ($P<0.05$) similar and higher CF digestibility when compared with those fed 5 and 0% PTLM inclusion (60.08 and 59.25%, respectively) which had significantly similar and lower CF digestibility . The ether extract (EE) digestibility was significantly ($P<0.05$) affected by PTLM inclusion, animals fed diet containing 5% PTLM inclusion (73.94%) had significantly higher EE digestibility than those fed 15, 0 and 5% PTLM inclusions (65.20, 64.22 and 62.01%, respectively) which their EE digestibility was significantly ($P<0.05$) lower and similar. There was also significant ($P<0.05$) difference in nitrogen free extract digestibility across the dietary treatments, animals fed 5% PTLM inclusion (65.39%) significantly ($P<0.05$) had the highest NFE digestibility compared with other dietary treatments.

Table 4.4.1: Nutrient Digestibility experimental diets containing varying levels of PTLM

Parameter (%)	Inclusion level of PTLM (%)				SEM
	0	5	10	15	
Dry matter	58.01	59.88	57.36	57.73	2.43^{NS}
Organic matter	58.54	59.99	57.71	58.63	1.93^{NS}
Crude protein	62.55	59.41	67.58	59.16	5.30^{NS}
Crude fibre	59.25^{b}	60.08^{b}	73.06^{a}	69.51^{a}	1.86*
Ether extract	64.22^{b}	73.94^{a}	62.01^{b}	65.20^{b}	2.90*
NFE	57.13^{b}	65.39^{a}	47.75^{d}	52.95^{c}	2.14*

[a, b, c, d] Means within row with different superscripts are significantly different ($p<0.05$), SEM= Standard Error of the Mean, NFE= Nitrogen free extract

4.4.2 Nutrient Digestibility of diets containing varying levels of PTPM

The result of the nutrient digestibility of on inclusion levels of PTPM is presented in Table 4.4.2.There was no significant (P>0.05) difference in the dry matter (DM) digestibility of Yankasa rams across the dietary treatments. Digestibility of organic matter and crude protein digestibility followed similar pattern with DM digestibility. The digestibility of crude fibre was significantly (P<0.05) affected by dietary treatments. Animals fed diets containing 10 and 15% PTPM inclusions had significantly (P<0.05) higher crude fibre digestibility (68.08 and 68.28%, respectively) which was followed by those fed 0 and 5% PTPM inclusions (64.28 and 60.39%, respectively) . The ether extract digestibility was significantly (P<0.05) different, animals fed 0 and 5% PTPM had significantly (P<0.05) higher digestibility (78.66 and 79.23%, respectively) than those fed 10 and 15% PTPM inclusions (65.66 and 68.02%, respectively) which significantly (P<0.05) lower and similar. There was significant (P<0.05) difference in nitrogen free extract digestibility, animals fed 15 and 10% PTPM inclusions (71.82 and 64.80%, respectively) were significantly (P<0.05) similar and higher than animals fed 0 and 5% PTPM inclusions (63.68 and 60.44%) which had significantly similar NFE digestibility.

Table 4.4.2: Nutrient Digestibility in Yankasa lamb rams fed diets containing varying levels of PTPM

Parameter (%)	Inclusion level of PTPM (%)				SEM
	0	5	10	15	
Dry matter	62.95	60.25	60.72	64.38	4.39^{NS}
Organic matter	63.63	61.02	61.04	64.75	3.96^{NS}
Crude protein	69.43	76.10	67.34	68.69	5.43^{NS}
Crude fibre	64.28^{a}	60.39^{b}	68.08^{a}	68.28^{a}	2.36*
Ether extract	78.66^{a}	79.23^{a}	65.66^{b}	68.02^{b}	3.16*
NFE	63.68^{ab}	60.44^{b}	64.80^{a}	71.82^{a}	4.40*

[a, b] Means within row with different superscripts are significantly different ($p<0.05$), SEM= Standard Error of the Mean, NFE= Nitrogen free extract

4.5 Nitrogen balance studies in Yankasa lamb rams

4.5.1 Nitrogen balance in Yankasa lamb rams fed diets containing varying levels of PTLM

The result from nitrogen balance in Yankasa lamb rams fed diets containing inclusion levels of PTLM is presented Table 4.5.1. There was significant ($P<0.05$) difference in the nitrogen intake (NI) in Yankasa lamb rams fed PTLM inclusions, animals fed 0 and 10% PTLM inclusion levels (24.38 and 23.80g/day, respectively) had significantly ($P<0.05$) similar and higher NI than those fed 5 and 15% PTLM inclusion (22.21 and 21.23%, respectively) in which their NI were significantly ($P<0.05$) different. There was no significant ($P>0.05$) difference in the faecal nitrogen (FN) across the dietary treatments. Urine nitrogen (UN) and total nitrogen losses (TNL) followed similar pattern with FN. The nitrogen absorbed in animals fed 10 and 0% PTLM inclusions (16.11 and 15.26g/day) was significantly ($P<0.05$) similar and higher than those fed 5 and 15% PTLM inclusions (13.19 and 12.61g/day, respectively) which had significantly similar nitrogen absorbed. The nitrogen retained in Yankasa lamb rams was significant ($P<0.05$), animals fed 0 and 10% PTLM inclusion (12.44 and 11.70g/day, respectively) had significantly ($P<0.05$) similar and higher nitrogen retained than those fed 5 and 15% PTLM inclusions (9.88 and 8.35g/day, respectively) which were significantly ($P<0.05$) lower and similar . There was significant difference in the nitrogen retained as percent of intake, animals fed 0 and 10% PTLM inclusions (50.99 and 49.12%, respectively) had significantly similar and higher nitrogen retained as percent of intake than those fed 5 and 15% PTLM inclusions (44.03 and 39.17%, respectively) in the animals fed the control and 10% PTLM (50.99 and 49.12 %, respectively) , while those fed diet containing 5 and 15% PTLM inclusion levels had

lower and similar nitrogen retained as percent of nitrogen intake (44.03 and 39.17%, respectively).

Table 4.5.1: Nitrogen balance in Yankasa lamb rams fed diets containing varying levels of PTLM

Parameter	Inclusion level of PTLM (%)				SEM
	0	5	10	15	
Nitrogen intake(g/day)	24.38[a]	22.21[b]	23.80[a]	21.23[c]	0.39*
Faecal nitrogen (g/day)	9.12	9.01	7.70	8.62	1.13[NS]
Urine nitrogen (g/day)	2.82	3.32	4.41	4.26	0.85[NS]
Total N losses (g/day)	11.94	12.33	12.11	12.88	0.93[NS]
N absorbed (g/day)	15.26[ab]	13.19[bc]	16.11[a]	12.61[c]	1.27*
N retained (g/day)	12.44[a]	9.88[bc]	11.70[ab]	8.35[c]	1.18*
NR as % of intake	50.99[a]	44.03[ab]	49.12[a]	39.17[b]	4.82*

[a, b, c,] Means within row with different superscripts are significantly different ($p<0.05$), SEM= Standard Error of the Means, NR= Nitrogen retained.

4.5.2 Nitrogen balance in Yankasa rams fed diets containing varying levels of PTPM

The result obtained from the nitrogen balance in Yankasa rams fed diets containing inclusion levels of PTPM is presented in Table 4.5.2. NI was significantly ($P<0.05$) affected by dietary treatments. Animals fed diet containing 5% PTPM inclusion level (32.75g/day) was significantly ($P<0.05$) higher than other dietary treatments, those fed 0% PTPM inclusion (27.52g/day) was significantly ($P<0.05$) higher when compared with those fed 15 and 10% PTPM inclusions (25.64 and 25.56g/day, respectively) which were significantly similar and lower. There was no significant ($P>0.05$) difference in the FN across the dietary treatments. UN and TNL follow similar pattern. Nitrogen absorbed was significantly affected by PTPM inclusions, animals fed 5% PTPM (24.99g/day) had significantly ($P<0.05$) higher nitrogen absorbed than those fed 0, 15 and 10% PTPM inclusion levels, (19.01, 17.62 and 17.25g/day, respectively) which were significantly ($P<0.05$) lower and similar. The nitrogen retained and nitrogen retained as percent of intake followed similar pattern with nitrogen absorbed.

Table 4.5.2 :Nitrogen balance in Yankasa rams fed diets containing varying levels of PTPM

Parameter	Inclusion level of PTPM (%)				SEM
	0	5	10	15	
Nitrogen intake(g/day)	27.52^{b}	32.75^{a}	25.56^{c}	25.64^{c}	0.61*
Faecal nitrogen (g/day)	8.51	7.76	8.32	8.03	1.52^{NS}
Urine nitrogen (g/day)	2.51	1.90	2.64	2.74	0.68^{NS}
Total N losses (g/day)	11.02	9.66	10.95	10.77	1.73^{NS}
N absorbed (g/day)	19.01^{b}	24.99^{a}	17.25^{b}	17.62^{b}	1.60*
N retained (g/day)	16.50^{b}	23.09^{a}	14.62^{b}	14.87^{b}	1.76*
NR as % of intake	60.23^{ab}	70.26^{a}	57.13^{b}	58.06^{b}	6.08*

[a, b, c,] Means within row with different superscripts are significantly different ($p<0.05$), SEM=Standard Error of the Means, N= Nitrogen, NR= Nitrogen retained.

4.6 Estimation of Methane Emission from Yankasa rams using Models

4.6.1 Modelling methane emission from Yankasa rams fed diets containing varying levels of PTLM

The results obtained from the models used in quantifying the methane produced by Yankasa lamb rams fed diets containing PTLM inclusions are presented in figure 1. Model 1 showed that animals fed 0 and 5% inclusion level of PTLM had the least methane produced, there was significant ($P<0.05$) difference in the quantity of methane produced by Yankasa lamb rams fed PTLM inclusions, animals fed 0 and 5% inclusion level of PTLM had significantly ($P<0.05$) similar methane production (1.52 and 1.53MJ/day) which differed significantly ($P<0.05$) from those fed 15 and 10% PTLM inclusions (1.56 and 1.58MJ/day) which were significantly ($P<0.05$) similar in their methane production. For model 2, there was significant ($P<0.05$) difference in the methane produced by Yankasa lamb rams fed PTLM inclusions, animals fed 5% PTLM inclusions (4.32L/day) had the least methane production and differed significantly ($P<0.05$) from other dietary treatment. For model 3, there was no significant ($P>0.05$) difference in the methane produced by Yankasa lamb rams across the dietary treatments although numerically, animals fed diet containing 15% PTLM inclusion had the highest methane production (39.02L/day) followed by those fed 0% and 10% PTLM inclusion with values 38.89 and 38.84L/day, respectively while animals fed 5% PTLM inclusion had the least (38.45L/day) methane production.

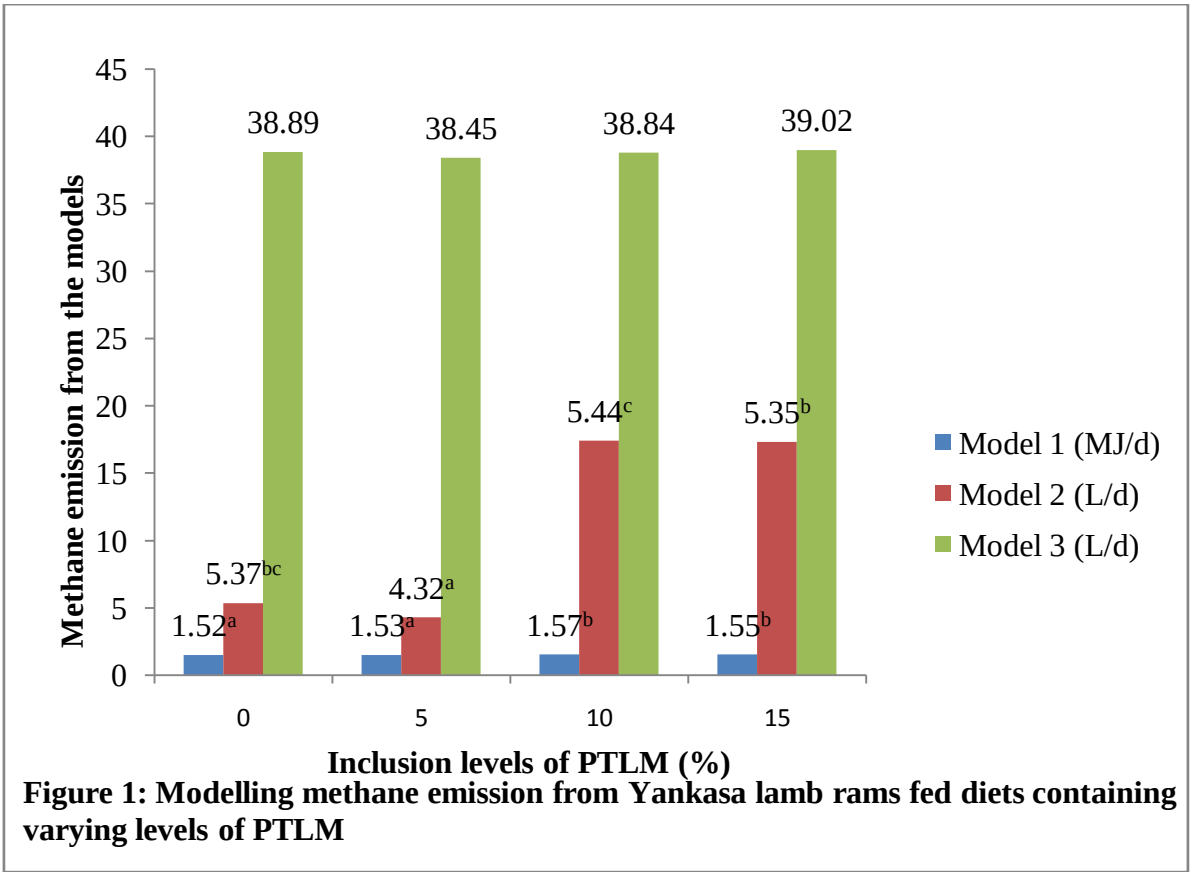


Figure 1: Modelling methane emission from Yankasa lamb rams fed diets containing varying levels of PTLM

4.6.2 Modelling methane emission from Yankasa lamb rams fed diets containing varying levels of PTPM

The results obtained from the models used in quantifying the methane produced by Yankasa lamb rams fed diets containing PTPM inclusions are presented in figure 2. For model 1, the result showed there was significant ($P<0.05$) difference in methane produced by Yankasa lamb rams fed diets containing PTPM inclusions. Animals fed 5 and 0% PTPM inclusions (1.55 and 1.56MJ/day) were significantly ($P<0.05$) similar in their methane production and also the least methane production was recorded among them compared to those fed 15 and 10% PTPM inclusions (1.59 and 1.58MJ/day, respectively) which had higher methane production that were significantly ($P<0.05$) similar. There was also significant ($P<0.05$) difference in the methane production by Yankas lamb rams for model 2, animals fed 0% PTPM inclusion (11.24L/day) produced the least methane and was significantly ($P<0.05$) different from other dietary treatments (13.09, 12.95 and 12.45L/day) which produced higher methane that were significantly ($P<0.05$) similar. There was no significant ($P>0.05$) difference in the methane produced by Yankasa of lamb rams fed PTPM inclusions across the dietary treatments for model 3, although numerically, highest methane production was recorded among animals fed 15 and 5% PTPM inclusions respectively (44.47 and 44.19L/day, respectively) while animals fed 0% PTPM inclusion (43.48L/day) produced the least methane followed by those fed 10% PTPM inclusion (43.92L/day).

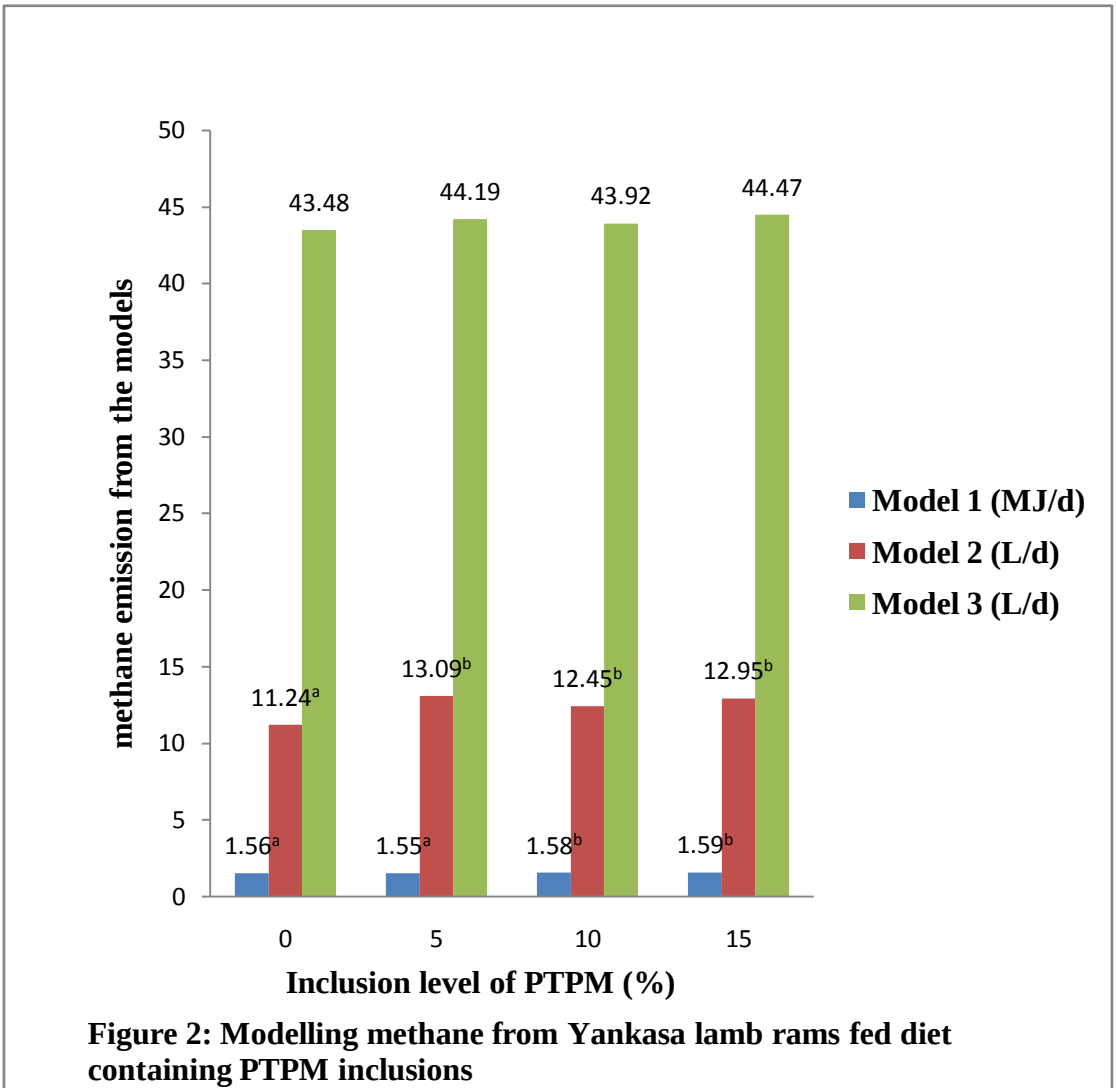


Figure 2: Modelling methane from Yankasa lamb rams fed diet containing PTPM inclusions

4.7 Effect of PTPM on rumen metabolites in Yankasa lamb rams

The result obtained from some rumen metabolites in Yankasa lamb rams fed diets containing inclusion levels of PTPM are presented in Table 4.7 There was no significant ($P>0.05$) difference in the pH of the rumen fluid of animals fed diets containing PTPM across the dietary treatments. There was significant ($P<0.05$) difference in the ammonia nitrogen (NH_3N) of animals fed varying inclusion levels of PTPM, animals fed 10 and 0% inclusion levels of PTPM (184.38 and 171.79mg/L) had significantly higher (NH_3N) compared to other dietary treatments followed by those fed 15% PTPM inclusion (161.26mg/L) which had significantly ($P<0.05$) similar NH_3N with those fed 5% PTPM (147.44mg/L). Total volatile fatty acid (TVFA) followed similar pattern with the pH, although numerically, TVFA peaks among animals fed 10% inclusion of PTPM (243.33mmol/L) followed by those fed 0 and 15% PTPM inclusions (230.00 and 222.22mmol/L) while TVFA was lowest among animals fed 5% PTPM inclusion (193.33mmol/L).

Table 4.7: Effect of varying inclusion levels of PTPM in the diets of Yankasa lamb rams on rumen metabolites

	Inclusion level of PTPM (%)				
Parameters	**0**	**5**	**10**	**15**	**SEM**
pH	6.22	6.22	6.32	6.33	0.27^{NS}
NH_3N (mg/L)	171.79^{a}	147.44^{b}	184.38^{a}	161.26^{ab}	15.36*
TVFA (mmol/L)	230.00	193.33	243.33	222.22	34.57^{NS}

[a b] Means within row with different superscripts are significantly different ($p<0.05$), SEM= Standard Error of the Mean, NH_3N = Ammonia nitrogen, TVFA = Total volatile fatty acid

4.8 Cost benefit of including *Piliostigma thonningii* in diets of Yankasa lamb rams

4.8.1 Cost benefit of including PTLM in diets of Yankasa lamb rams

The results obtained from the cost benefit of including *Piliostigma thonningii* leaf meal in diet of Yankasa lamb rams are presented in Table 4.8.1. There was no significant (P >0.05) difference in the DFI across the dietary treatment. The TFI and cost of feed consumed follow similar pattern with DFI. There was significant (P<0.05) difference in the DLWG of Yankasa lamb rams fed diet containing PTLM inclusions, animals fed 5% inclusion level of PTLM (169.64g) had significantly (P<0.05) different and higher DLWG compared to other dietary treatments while the DLWG of those fed 0 and 15% PTLM inclusions (133.93, 133.93g) were significantly (P<0.05) similar but significantly (P<0.05) higher than animals fed 10% PTLM inclusion (1116.07g). There was significant (P<0.05) difference in the cost per kg of feed across the dietary treatment, the least cost was recorded in diet containing 15% PTLM inclusion (₦38.44 per kg). The cost of feeding per animal per day followed similar pattern with cost of per kg feed.

Table 4.8.1: Cost benefit analysis of including PTLM in the diets of Yankasa lamb rams in Northern Guinea Savannah of Nigeria

Parameter	Inclusion level of PTLM (%)				SEM
	0	5	10	15	
Daily feed intake (g)	915.66	951.82	987.05	978.91	58.05^{NS}
Total feed intake (kg)	12.82	13.33	13.82	13.71	0.81^{NS}
DLWG (g)	133.93^{b}	169.94^{a}	116.07^{b}	133.93^{b}	15.64*
Cost/kg feed(₦)	47.35^{d}	44.38^{c}	41.13^{b}	38.44^{a}	0.00*
Cost of feeding(h/day₦)	43.38^{d}	42.24^{c}	40.60^{b}	37.63^{a}	0.00*
Cost of feed consumed(₦ /a)	606.99	591.39	568.35	526.81	35.71^{NS}

[a, b, c ,d] Means within row with different superscripts are significantly different ($p<0.05$), SEM = Standard Error of the Mean, DLWG - Daily live weight gain, h – head

4.8.2 Cost benefit of including PTPM in diet of Yankasa lamb rams

The results obtained from the cost benefit of including *Piliostigma thonningii* pod meal in diet of Yankasa lamb rams are presented in Table 4.8.2. There was no significant ($P > 0.05$) difference in the DFI across the dietary treatments. Also the TFI followed similar pattern. There was significant ($P<0.05$) difference in the DLWG by Yankasa lamb rams fed PTPM inclusions, animals fed 5, 0 and 15% PTPM inclusions had significantly ($P<0.05$) similar and higher DLWG than those fed 10% PTPM inclusion which was significantly ($P<0.05$) lower. There was significant ($P<0.05$) difference in the cost per kg of feed across the dietary treatment with least cost in diet containing 15% PTPM inclusion (₦27.03 per kg).The cost of feeding per animal per day and the cost of feed consumed followed similar pattern with cost per kg of feed.

Table 4.8.2: Cost benefit analysis of including PTPM in the diets of Yankasa rams in Northern Guinea Savannah of Nigeria

Parameter	Inclusion level of PTPM (%)				SEM
	0	5	10	15	
Daily feed intake (g)	1401.0	1379.80	1394.50	1398.10	167.64^{NS}
Total feed intake (kg)	19.61	19.32	19.52	19.73	2.36^{NS}
DLWG (g)	178.57	187.50^{a}	142.86^{b}	169.64^{a}	15.64*
Cost/kg feed(₦)	43.11^{d}	$38 \cdot 22^{c}$	32.17^{b}	27.03^{a}	0.00*
Cost of feeding(h/day₦)	60.40^{d}	52.74^{c}	44.86^{b}	37.79^{a}	5.78*
Cost of Feed consumed(₦ /a)	845.50^{d}	738.30^{c}	628.10^{b}	533.30^{a}	81.34^{*}

[a b, c, d] Means within row with different superscripts are significantly different ($p<0.05$), SEM= Standard Error of the Mean, DLWG- Daily live weight gain, h- head

CHAPTER FIVE

5.0 DISCUSSION

5.1 Proximate composition of PTLM and PTPM

The higher dry matter composition of PTLM recorded in this study could be as a result of the drying condition of the leaf compared with 90.25% reported by Tona (2011). The crude protein content of PTLM obtained in this study does not agree with 16.25% reported by Tona *et al*. (2010) and 15.25% (Tona, 2011) and also lower than the range 15.08 - 22.74% for tropical browse plant fed to sheep reported by Astutia *et al*. (2011). The difference in the result could be due to the nature of the leaves harvested (age, tender or older leaves). Protein is required for most normal functions of the body, including maintenance, growth and reproduction therefore it is important to feed enough protein to cover the nutritional requirement of the animal (David, 2014). The crude fibre of PTLM obtained in this study agrees with the findings of Tona (2011) who reported that *Panicum maximum* contain more fibre than *P. thonningii* leaf.

From dry matter content of PTPM recorded in this study, the difference in the result compared with the findings of Jimoh and Oladiji, (2005) for *P.thonningii* seed could be as a result of mixture of pod and seed adopted in this study. The crude protein content of PTPM recorded in this study fell within the range of the protein content of all legumes except soyabean (20 - 25%) reported by Apata and Ologhobo, 1994; Ene-Obong and Carnovale, (1992) but higher than 7.87% reported by Sibanda and Ndlovu, (1992), however, it did not agree with 30.33± 0.31% reported by Jimoh and Oladiji, (2005) for *P. thonningii* seed who concluded based on the high value recorded that *P. thonningii* seed could be a cheap source of protein in some feed formulation. The crude fibre content in PTPM used in this study

was lower than 35.03± 0.11% reported by Jimoh and Oladiji, (2005) for *P.thonningii* seed which could also be as a result of mixture of pod and seed adopted in this study. It could be inferred from the low ether extract recorded that *P. thonningii* is not an oil producing plant (Jimoh and Oladiji, 2005) but was within the range reported by Apata and Ologhobo, (1994); Ene-Obong and Carnovale, (1992); Swaminathan and Jain, (1973) that legumes except oil legumes have low fat content ranging from 1- 5%. Also the ash content of PTPM recorded in this study was higher than that reported by Jimoh and Oladiji, 2005 **(**3.50± 0.04%) and is within the range of other legumes (3.0 to 4.8%) reported by Elegbede, (1998)

5.2 Antinutritional content in PTLM and PTPM

The saponin present in PTLM recorded in this study was lower than that of tropical browse plants (2.80- 5.97%) fed to sheep reported by Astutia *et al*., (2011). Also the oxalate present in *P. thonningii* leaf in this study did not agree with the 1.26% reported by Tona (2011) but falls within the recommended level of 2.5% maximum for small ruminant by NRC, 1985.

The difference in saponin present in PTPM recorded compared with the value reported by Hemen *et al*., (2012) for whole *P. thonningii* seed **(**12.07 ± 0.10%) may be due to the mixture of seed and pod or stage of harvest. The oxalate recorded in this study was lower than 10.00 ± 0.01% reported for the whole seed by Hemen *et al***. (**2012). Also the trypsin inhibitor recorded in this study was lower than (14.00 ± 0.00%) reported for whole seed (Hemen *et al*., 2012) which could also be due the mixture of pod and seed adopted in this study. The result recorded in this study for flavonoids revealed the presence of flavonoids

reported by Jimoh and Oladiji, (2005) in the preliminary studies carried out on *P. thonningii* seed.

5.3 Chemical composition of the experimental diet

The dry matter composition of the experimental diet recorded in this study revealed the dryness of the leaf and probably the method of processing, formulation of PTLM with other feed ingredient or climatic condition of the location of harvest. The crude protein content in PTLM compounded with other feed ingredient was adequate compared with the range 7 - 8% crude protein recommended as the least value required by ruminants for efficient performance (Mildford and Minson, 1967; Tona, 2011).

The crude protein content of inclusion levels of PPTM formulated with other feed ingredient recorded in this study was adequate to meet the nutritional requirement of animals, David, (2014) reported that feeding adequate to slightly greater amount of protein than required appears to aid in the control (both resistance and resilience) of internal nematode parasite. The crude fibre of PTPM was lower in a decreasing trend as the inclusion level increases. Jimoh and Oladiji, (2005) reported that crude fibre enhances digestibility but when high in diet can cause intestinal irritation, lower digestibility and overall decreased nutrient utilization.

5.4 Performance of Yankasa lamb rams fed PTLM and PTPM inclusions

The ADWG of the animals fed PTLM inclusions in this study does not agree with the findings 44- 48g/day reported by Astutia *et al*. (2011) when tropical browse plants were fed to evaluate the rumen fermentation, blood metabolites and performance of Sheep. The increase in the ADWG may be as a result of the presence of saponin in PTLM in conjunction with Astutia *et al*. (2008) who attributed final effect in performance by

improving daily gain and health status to the presence of saponin. The ADFI was not in agreement with the result obtained by (Astutia and Sastradipradja, 1999) who reported that local Sheep with 19kg body weight consumed 500g/head/day of ration and Astutia *et al*. (2011) who also reported that Sheep consumed 555 ± 56g/head/day and met their maintenance and growing requirement. The FCR was best in animals fed 5% inclusion level which implies PTLM consumed was converted into body tissue giving a resultant effect of higher final weight and weight gained by the animals, Astutia *et al*. (2011) reported that offering some tropical legumes in regulated quantity improves growth response. There was no significant (P>0.05) difference in the daily water intake by Yankasa lamb rams fed PTLM inclusions, the low intake of the animals could be attributed to the climatic condition at the period the experiment was carried out. Animals tend to drink less while the feed intake increases during cold weather. Total water intake by the animals followed similar pattern.

The daily feed intake in this study increased as PTPM inclusion level increases. The increase in the level of intake as inclusion level increase may be due to the decrease in the fibre content of the diet with increasing level of PTPM in the diet which agrees with findings of Jimoh and Oladiji, (2005) who reported that high crude fibre diet causes intestinal irritation thereby decreasing the overall nutrient utilization. Animals fed 5% PTPM inclusion level gained more, a resultant of the animals having the best FCR. Yankasa lamb rams fed 5% inclusion level of PTPM had numerically greater daily weight gain (187.50g) compared with other inclusion. The lower water intake which followed similar pattern with animals fed varying inclusion levels of PTLM may be as a result of the climatic condition when the experiment was carried out, animal in terms of variation, age and body weight.

5.5 Nutrient digestibility of PTLM and PTPM inclusions fed to Yankasa lamb rams

The lower dry matter digestibility of the feed by the animals fed diet containing inclusion levels of PTLM compared with values (61.60 and 63.50%) reported by Tona (2011) when *Panicum maximum* was supplemented with 20% *P. thonningii leaf* in the diet of West African Dwarf rams may be due to stage of maturity of PTLM used in this study. The crude protein digestibility recorded in this study was similar to 59.18 and 60.82% reported by Tona (2011). *P. thonningii* was suggested to provide additional source of protein for rumen microbes which allowed active fermentation and degradation of fibrous diets (Singh *et al*., 1979; Tona, 2011) which could also be a reason for the increase in crude fibre digestibility as the inclusion level of PTLM increases. Tbezinda and Eik, (2007) reported that browses use to have moderate crude fibre digestibility**.**

The dry matter digestibility of PTPM recorded in this study increases with inclusion of PTPM, the values were within the range of 62 ± 2 - 69 ± 0.43% reported by Astutia *et al*. (2011).The digestibility of crude protein by animals fed PTPM inclusions was higher than the range 40 - 60% reported for browses used for animal utilization (Devendra, 2007). Also, sufficient nutrient to meet both rumen microbial and host animal's nutrient requirement can only be met by higher crude protein (Leng, 1990; Savadogo *et al*., 2007). The crude fibre digestibility of the animals decreases upon inclusion of PTPM, the values recorded in this study was a little higher than 40 – 60% range reported for moderate crude fibre digestibility for browse plants (Devendra, 2007), the little increase might be attributed to the soil and climatic difference of the location of harvest.

5.6 Nitrogen balance in Yankasa lamb rams fed PTLM and PTPM inclusions

There was significant difference in nitrogen (N) intake of Yankasa lamb rams across the dietary treatment. The faecal nitrogen reduces as the level of PTLM in the diet increases while the least loss was recorded in animals fed 10% PTLM inclusion. The nutritional demands of ruminants highlight the synchronization between protein and dietary carbohydrates in the rumen to maximize microbial synthesis thereby reducing nitrogen loss (Bastos *et al*., 2014). But for urine nitrogen, losses increases with further inclusions of PTLM. Animals fed 10% PTLM inclusion ranked highest in their nitrogen absorbed while those fed 15% PTLM inclusion had the least nitrogen retained compared with other inclusion levels, according to Wanapat *et al*. (2013), N excretion and retention could reflect differences in N metabolism because N balance was the most important index of protein nutrition status in ruminants (Orskov, 1999). The nitrogen intake (%) was higher among animals fed diet without PTLM inclusion compared with those fed diets containing PTLM inclusion levels.

Animals fed 5% inclusion level of PTPM had the highest nitrogen intake with least losses of nitrogen recorded in the faeces and urine. The total nitrogen loss was lower in animals fed 5% PTPM which further reduces with increased levels of PTPM, while greater N- loss was recorded among animals fed diet without PTPM inclusion. The nitrogen absorbed and nitrogen retained ranked highest among animals fed 5% PTPM inclusion level. Retention of nitrogen is considered as the most common index of protein status of ruminant or is a good estimate of the quantity of nitrogen available for deposition in body tissues (Bastos *et al*., 2014; Yulistiani *et al*., 2015.The nitrogen intake (%) followed similar pattern.

5.7 Estimation of methane emission from Yankasa lamb rams fed PTLM and PTPM inclusions

Fitting into model 1, the result of this study reveals that animals fed concentrate alone had the least methane emission compared to those fed inclusion levels of PTLM. This probably suggest dietary substrate affects the amount of CH_4 produced (Blaxter and Clapperton, 1965; Beauchemin *et al*., 2008) due to changes in ruminal pH and microbiota present (Johnson and Johnson, 1995); in particular through feeding of concentrates also Beauchermin *et al*. (2008) and Goel and Makkar, (2012) reported that methane emission from ruminants fed high roughage diets are generally higher than those fed concentrates. Fitting the result into model 2, there was significant ($P<0.05$) difference across the dietary treatment. Animals fed 5% PTLM inclusion had the least methane production while the highest production was recorded among those fed 10% inclusion of PTLM. The reduction in the quantity of methane produced could be due to nutrient content and presence of beneficial secondary compounds in *P. thonningii* leaf coupled with it being a leguminous forage. Methane emission from animals fed legume forages have been reported to be lower than in those animals fed grass silage (Waghorn *et al*., 2002). Also, lower emission from animals fed legume forages is often explained by the presence of condensed tannin, lower fibre content, higher dry matter intake and faster rate of passage from the rumen (Beauchemin *et al*., 2008). There was no significant ($P>0.05$) difference across the dietary treatment for model3.

There was significant ($P<0.05$) difference across the dietary treatment when fitted into model 1 with animals fed 5% PTPM inclusion having the lowest methane emission. The reduction in the quantity of methane produced could be due to the presence of saponin in PTPM, saponin was reported to have an inhibitory effect on methanogenesis which varies

with plant source ranging from 5 – 60% accompanied by enhanced proprionate (Wina *et al*., 2005). Also, Yasuo (2010) reported that rumen protozoa are particularly sensitive to saponins which reduces their population (defaunation) in the rumen, resulting in the depression of methanogens associated with protozoa. In model 2, animals fed concentrate only produced lesser methane compared with animals on varying inclusion level of PTPM. There was no significant (P>0.05) difference in the emission of methane by Yankasa rams across the dietary treatments for model 3.

5.8 Effect of PTPM inclusions on rumen metabolites in Yankasa lamb rams

The rumen pH of animals fed PTPM inclusion levels recorded in this study was within the range 6.2- 7.2 reported as being optimal for fibre digestion (Van Soest, 1994) and range 5.5- 6.5 reported by Kolver and de Venth, (2002) for ruminants fed with larger proportion of concentrates. The ammonia nitrogen recorded in this study was lower than 191.33mg/L reported by Isah *et al*. (2014) on animal fed *P. thonningii* but higher than the minimum acceptable level (150mg/L) recommended for optimization of fibre degradation in the rumen (Leng, 1990). The total volatile fatty acid recorded in this study did not agree with the findings 72.33- 168.67mmol/L recorded in animals fed browse foliage and also higher than that reported for *P. thonningii* (90.67mmol/L) Isah *et al*. (2014).

5.9 Cost benefit of including PTLM and PTPM in diet of Yankasa lamb rams

This study revealed that the cost of including PTLM and PTPM in diet of Yankasa lamb rams reduces as the inclusion level increases. This may suggest the usage of PTLM and PTPM as alternative feed or inclusion in ruminant feed particulary during the dry season when rangeland are completely overgrazed especially in the Northern part of Nigeria**.** Adegbola, (2002) reported that the supply of adequate feeds in terms of quality and

quantity for small ruminant production becomes critical during the dry season period. The cost of feeding the animals also throughout the experiment also decreased as PTLM inclusion and PTPM inclusion levels increase although animals fed 5% PTLM inclusion and PTPM inclusion performed best in terms of weight gained and reduction in the quantity of methane emitted. Fall-Touré *et al.*, (1998); Aganga and Mosase, (2001) reported that a number of browse plants (include legumes and herbs) may also contain chemical compounds such as protein, fibre, mineral, and vitamin concentrations adequate for the maintenance requirement of grazing animals.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

A comparative study was carried out to determine the effect of feeding varying inclusion levels of *P. thonningii* product (leaf and pod meals) to Yankasa lamb rams on growth performance, nutrient digestibility, nitrogen balance, methane emission, rumen metabolites and cost of inclusion in the diet. *P. thonningii* tree is highly utilized by local people because of its usefulness medicinally, *P. thonnigii* product (leaf and pod meals) are being consumed by ruminants because of their high nutritional value especially when formulated with other feed ingredients.

Eight Yankasa lamb rams aged 6-9 months having average weight range 18-23kg were used for this study. Four (4) complete diets were formulated to contain crude protein ranging between 13.91 and 13.59% comprising of 0, 5 10 and 15% inclusion levels of PTLM and PTPM respectively with other feed ingredients. Experimental animals were randomly allotted to four dietary treatments in a 4x4 Latin Square Design.

Growth performance, nutrient digestibility, nitrogen balance, methane emission, rumen metabolites and cost benefit analysis of including *P.thonningii* products were evaluated. The result from this study showed that *P.thonningii* leaf and pod meals can be included in the diet of Yankasa lamb rams of which better performance and least reduction in the quantity of methane was recorded at 5% inclusion level for both products compared to other dietary treatment. However, rumen metabolites was best at 10% inclusion level of PTPM and the least cost was recorded in the highest inclusion level of *P.thonningii* products (leaf and pod meals).

6.2 Conclusion

- This study revealed that PTLM at 5% inclusion level in a complete diet of Yankasa rams improved growth performance by 27%, nutrient digestibility (14%) and nitrogen balance (13%).
- Inclusion of 5% PTPM in a complete diet improved growth performance of Yankasa rams by 5%, nutrient digestibility (5%) and nitrogen balance (17%).
- Inclusion of PTLM (5%) in a complete diet reduced the amount of methane emission from Yankasa rams by 20%.
- Inclusion of PTPM (5%) in a complete diet reduced the amount of methane emission from Yankasa rams by 16%.
- Cost of including PTLM and PTPM reduces as the inclusion level increases in the diet although best performance was recorded at the least inclusion level.

6.3 Recommendation

Inclusion of 5% PTLM in the diet of Yankasa rams based on the result obtained from this study is therefore recommended for improved performance, enhanced digestibility and reduction in the amount of methane emission, a powerful greenhouse gas.

PTPM at 5% inclusion level in the diet of Yankasa rams is recommended for efficient performance, enhanced digestibility and reduction in the amount of methane released into the environment thereby reducing the contribution of Sheep in climate change.

REFERENCES

Adebowale, O.A. (2012). Dynamics of Ruminant Livestock Management in the Context of the Nigerian Agricultural system, ISBN 978-953-51-0814-6, DOI: 10.5772/52923.

Adegbola, T.A. (2002). Nutrient intake, digestibility and rumen metabolites in bulls fed rice straw with or without supplement. *Nigerian Journal of Animal Production*, 29(1): 40-46.

Aderogba, M.A., Okoh, E.K., Adelanwa, T.A. and Obuotor, E.M. (2004). Antioxidant properties of the Nigerian *Piliostigma species*. *Journal of Biological Sciences*, 4(4): 501–503.

Adegun, M.K. and Aye, P.A. (2013). Growth performance and economic analysis of West African Dwarf Rams fed *Moringa oleifera* and cotton seed cake as protein supplements to *Panicum maximum*. *American Journal of Food and Nutrition*, 3(2): 58-63.

Adu, I.F. and Ngere, L.O. (1979). The indigenous sheep of Nigeria. *World Review of Animal Production*, 15(3): 51-62.

Aganga, A.A. and Mosase, K.W. (2001). Tannin content, nutritive *Lonchocarpus capassa*, *Ziziphus mucronata*, Sclerocarya birrea, Kirkia acuminata and *Rhus lancea* seed. *Animal Feed Science Technology*, 91: 107–11.

Ahamefule, F.O., Ibeawuchi, J.A. and Agu, C.I. (2006). Comparative evaluation of some forages offered to goats in Umudike Southeastern Nigeria. *Journal of Sustainable Tropical Agricultural Research*, 18:79-86.

Alderman, G. (1985). Prediction of the energy value of compounds feed. In: Haresign and D. J. Cole (eds). *Recent Advances in Animal Nutrition.* Butterworth, London , U.K.19.

Alli-Balogun, J.K., Lakpini, C.A.M., Alawa, J.P., Mohammed, A. and Nwanta, J.A. (2003). Evaluation of cassava foliage as a protein supplement for sheep. *Nigerian Journal of Animal Production*, 30: 37-46.

Ammar, H., Lo´ pez, S., Gonza´lez, J.S. and Ranilla, M.J. (2004). Chemical composition and in - vitro digestibility of some Spanish browse plant species. *Journal of the Science of Food and Agriculture*, 84:197-204.

Andrew, A.J., Nasiru, A., Dauda, A. and Yakubu, N.R. (2017). Effect of graded levels of browse forage (*Balanites aegyptiaca*) leaves inclusion in the diets of growing rabbits. *Online Journal of Animal and Feed Research*, 7(2): 38-42.

Annison, E.F., Lindsay, D.B. and Nolan, J.V. *(*2002*).* Digestion and metabolism. In Sheep nutrition: Chapter 5. *In* M. Freer & H. Dove *(Eds.), Sheep nutrition*. Wallingford*: CABI Publication in association with CSIRO Publication*, 95-118.

AOAC (2005). Official Method of Analysis. Association of Official Analytic Chemist, 17th Edition, Washington DC., USA.

Apata, D.F. and Ologhobo, A.D. (1994). Biochemical evaluation of some Nigerian legumes seeds. *Food Chemistry Journals*, 49: 333-338.

Apori, S.O., Castro, W.J., Shand, W.J. and Orskov, E.R. (2007). Chemical composition, *in sacco* degradation and *in vitro* gas production of some Ghanian browse plants. *Animal Feed Technology*, 76(1-2):129-137.

Aregawai, T., Melaku, S. and Nigatu, L. (2008). Management and utilization of browse species as livestock feed in semi-arid district of North Ethiopia. *Livestock Resources Rural Development* 20. www.lrrd.org/lrrd20/6/areg20086.htm.

Aregheore E.M (2000). Chemical composition and nutritive value of some tropical by – product feedstuffs for small-ruminants *in vivo* and *in vitro* digestibility. *Animal Feed Science and Technology*, 85(1) : 99 – 109.

Aribido ,S.O., Afolabi, A. and Jari, S. (2017). Principles of Animal Production. *National Open University of Nigeria School of Science and Technology course guide*, ISBN: 978-058 908-8 http://nouedu.net/sites/default/file/ANP%20202_0.

Aro, S.O., Aletor, V.A., Tewe, O.O. and Agbede, J.O. (2010). Nutritional potentials of cassava tuber wastes: A case study of a cassava starch processing factory in south-western Nigeria. *Livestock Resources Rural Development*, 22 (11).

Asaolu,V.O., Akinlade,J.A., Aderinola, O.A., Okewoye, A.T. and Alalade, J.A. (2012). Performance of Grazing West African Dwarf Goats on Moringa Multinutrient Block Supplementation. *Asian Journal of Animal Sciences*, 6: 263-277.

Astutia, D.A. and Sastradipradja, D. (1999). Energy metabolism in relation to grazing activity in growing priangan sheep as affected by rations. *Indonesian Journal of Tropical Agriculture*, 3: 1-11.

Astutia, D.A., Ekastuti, D.R. Marwah, R.D and Suryani, A.D. (2008). Blood profile and hematologycal status of local sheep under the rain forest area Walat-Sukabumi. *Journal of Ilmu Ternak Unsyah*, 1: 1-9.

Astutia, D.A., Babab, A.S. and Wibawanc, I.W.T. (2011). Rumen fermentation, blood metabolites, and performance of sheep fed tropical browse plants. *Media Peternakan*, 201-206.

Asuzu, I.U. and Onu, U.O. (1994). Anthelmintic activity of the ethanolic extract of *Piliostigma thonningii* bark in Ascaridia galli infected chickens. *Fitoterapia*, 65(4): 291–297.

Asuzu, I.U., Gray, A.I. and Waterman, P.G. (1999). The anthelmintic activity of D-3-O methylchiroinositol isolated from *Piliostigma thonningii* stem bark. *Fitoterapia*, 70(1): 77–79.

Ayisire, B.E., Akinro, L.A. and Amoo, S.O. (2009). Seed germination and in vitro propagation of *Piliostigma thonningii* – an important medicinal plant. *African Journal of Biotechnology*, 8(3): 401-404.

Bastos, M.P.V., Carvalho, G.G.P., De Pires, A.J.V., Silva, R.R., Filho, A.E., Dos Santos, E.D.J., Filho, G.A. (2014). Ingestive Behaviour and Nitrogen Balance of confined Santa Ines Lambs fed diets containing soybean hulls. *Asian-Australian Journal of Animal sciences*, 27(1):24- 29.

Beauchemin, K.A., Kreuzer, M., Mara, F.O. and. McAllister, T.A. (2008). Nutritional management for enteric methane abatement: a review. *Australian Journal of Experimental Agriculture*. 48:21-27.

Beecher, G.R. (2003). "Overview of dietary flavonoids: nomenclature, occurrence and intake". *Nutrition Journal.* 133 (10).

Bergman, E.N. (1990). Energy contributions of volatile fatty acids from the gastrointestinal tract in various species. *Physiological Reviews,* 70: 567–590.

Beyzavi, M.H., Stephenson, C.J., Liu, Y., Karagiaridi, O., Hupp, J.T., and Farha, O.K. (2015). Metal–organic framework-based catalysts: chemical fixation of CO2 with epoxides leading to cyclic organic carbonates, *Frontier Energy Research,* 2:63.

Blaxter, K.L. and Clapperton. J.K. (1965). Prediction of the amount of methane produced by ruminants. *Brazilian Journal of Nutrtion,* 19:511-522.

Briggs, P.K., Hogon, J.P. and Reid, R.C. (1957). Effect of volatile fatty acid, lactic acid and ammonia on rumen pH in sheep. *Australian Journal of Agricultural Research,* 8:674

Britton, R., and Krehbiel, C. *(*1993*).* Nutrient Metabolism by Gut Tissues 1. *Journal of Dairy Science,* 76:125–2131.

Cook, N.S. and Samman, S. (1996). Flavonoids – Chemistry, metabolism, cadioprotective effect and dietary sources. *Journal of Nutrition Biochemistry*, 7: 66-76.

CSIC - Spanish National Research Council (2016). "Methane production reduced in ruminants: 3 nitrooxypropanol compound reduces greenhouse gas levels with no risk to the animal's health. *Science Daily*. www.sciencedaily.com/releases/160502161108.htm.

David, G.P. (2014). Nutrient requirement of Goats. The Merck Veterinary Manual. Retrieved from http://www.merck.manuals.com/vet,index.Html.

Devendra, C. 2007. Goats: Biology,Production and Development in Asia. *Academy of Sciences Malaysia*. 902(4):131.

Diego, M.G. (1994). Nutrient Requirements of Sheep and Goats. *Alabama Cooperative Extension system*. ANR-812. http://www.aces.edu/pubs/docs/A/ANR-0812/ANR0812.pdf.

Elegbede, J.A. (1998). Legumes. In: Nutritional quality of plant foods. Osagie, A.U., Eka, O.U. (Eds). Post Harvest Research Unit, University of Benin, 53-83.

Ene-Obong, H.N, Carnovale, E. (1992). A comparison of the proximate, mineral and amino acid composition of some known and lesser known legumes in Nigeria. *Food Chemistry,* 43: 169-175.

EPA (2016). Inventory of U.S Greenhouse Gas Emission and Sinks: 1990-2014. The seal of the United State, Environmental Protection Agency (EPA). https://www3.epa.gov/climatechange/ghgemisssions/gases.html.

Evans, W.C. (2002). *Trease and Evans Pharmacognosy*. 15th Edition, Elsevier, India, 27, 46,183-184, 289-291, 411-413, 434, 485-486.

Evert, C.D., Tristan, W., Seigo, S., Divya, P., Bryan, C., David, R., Yáñez, R., Stephane, D., Robert, R., René, T.S., Rudolf, K.T. and Maik, K. (2016). Mode of action uncovered for the specific reduction of methane emissions from ruminants by the small molecule 3 nitrooxypropanol. *Proceedings of the National Academy of Sciences*. DOI:10.1073/pnas.1600298113.

Fajemisin, A.N., Alokan, J.A., Aro, S.O., Alowofeso, O. and Fawolu, T.S. (2010). Nutrient intake, Digestibility and Weight gain of West African Dwarf Sheep fed rumen content – poultry droppings mixed diets. *Proc.33rd Annual Conference, Nigeria Society for Animal Production*, 583 - 586.

Fall-Touré, S., Michalet-Doreau, B. Traoré, E., Friot, D. and Richard, D. (1998). Occurence of digestive interactions in tree forage-based diets for sheep. *Animal Feed Science and Technology,* 63: 63–78.

Food and Agriculture Organization [FAO]. (2004). Production Year Book. http://faostat.fao.org.

Food and Agriculture Organization [FAO] Regional office for AFRICA ACCRA, (2014). Crop residues and agro-industrial by-products in West Africa. ISBN 978-92-5-108113-6 (print) E-ISBN 978-92-5- 108114-3.

Food and Agriculture Organization of the United Nations FAO- (2016) http://www.fao.org/contact-us/terms/en.

Fayemi, P.O., Onwuka, C.F.I., Isah, O.A., Jegede, A.V., Arigbede, O.M. and Muchenje, V. (2011). Effects of mimosine and tannin toxicity on rabbits fed processed *Leucaena leucocephala* (Lam) De Wit. leaves. *African Journal of Agricultural Research*, 6(17):4081-4085.

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G., Nganga, J., Prinn, R., Raga, G., Schulz, M. and Van Dorland, R. (2007). Changes in atmospheric constituents and in radiative forcing. In: S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller, (eds). *Climate Change: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY**,** 129–234.

Gatenby, R.M. (2002). Sheep. *Macmillan Publishers*, 60:63, 156-158.

Goel, G. and Makkar, H.P.S. (2012). Methane mitigation from ruminants using tannins and saponins. *Tropical Animal Health and Production*, 44:729-739.

Georing, H.K. and Van Soest, P.J. (1970). *Forage Fiber Analysis Agric*. Handbook No. 379. ARS, USDA, Washington DC.

Giani, S.Y. (1993). Effect of processing on the proximate composition and functional properties of cowpea (*Vigna unguiculata*) flour. *Food Chemistry,* 47: 153-158.

Gilani ,G.S, Cockell ,K.A. and Sepehr, E. (2005). "Effects of antinutritional factors on protein digestibility and amino acid availability in foods". *Journal of Association of Analytical Chemists international,* 88 (3): 967–87.

Gressley, T.F., Hall, M.B. and Armentano, L.E. (2011*).* Ruminant nutrition symposium: Productivity, digestion, and health responses to hindgut acidosis in ruminants. *Journal of Animal Science,* 89:1120–1130.

Habtamu, F. G. and Negussie, R. (2014). Antinutritional Factors in Plant Foods: Potential Health Benefits and Adverse Effects. *International Journal of Nutrition and Food Sciences,* 3(4): 284-289.

Hemen, J.T., Johnson, J.T, Fila, W.A., Odey, M.O. and Inwang, E.U. (2012). Effect of Processing Methods on Some Anti Nutrients Composition of Premature and Mature Fruits of *Piliostigma Thonningii* from Guinea Savanna Zone of Nigeria. *ARPN Journal of Science and Technology***,** 2(7). http://www.ejournal of science.org.

Heuze, V., Tran, G., Bastianelli, D., Brossard, L., Hassoun, P. and Lebas, F. (2013). Cotton seeds. Feedipedia.org. A prpgramme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/742. Last updated on May 29, 9:44

Heuzé, V., Tran, G., Archimède, H., Régnier, C., Bastianelli, D.and Lebas, F. (2016). Cassava peels, cassava pomace and other cassava by-products. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/526[13:50:22.

Hotz, C. and Gibson, R.S. (2007).Tradition food –processing and preparation practices to enhance the bioavailability of micronutrients in plant –based diets. *Journal of Nutrition* 137 (4): 100-1097.

Hristov, A.N., Oh, J, Giallongo, F., Frederick, T.W., Harper, M.T., Weeks, H.L. (2015). An inhibitor persistently decreased enteric methane emission from dairy cows with no negative effect on milk production. Proceedings of National Academy of Sciences of the United States of America, 112:10663– 8.10.1073/pnas.1504124112.

Hutagalung, R.I. (1981). The use of tree crops and their by-products for intensive animal production. *British Society of Animal Production, Occasional Publication*, 151-184.

I.A.R. (2016).Weather Report. Institute of Agricultural Research, Samaru. Ahmadu Bello University, Zaria, Kaduna State.

Ibewuike, J.C., Ogundaini, A.O., Ogungbamila, F.O., Martin, M.T., Gallard, J.F., Bohlin, L. and Pais, M. (1996). Piliostigmin, a 2-phenoxychromone, and C-methylflavonols from *Piliostigma thonningii*. *Phytochemistry*, 43(3): 687–690.

Ibewuike, J.C., Ogungbamila, F.O, Ogundaini, A.O., Okeke, I.N. and Bohlin, L. (1997). Antiinflammatory and antibacterial activities of C-methylflavonols from *Piliostigma thonningii Phytotherapy Research* 11(4): 281–284.

Ida, M.L.D., Storm, A.L., Hellwing, F., Nicolaj, I.N. and Jorgen, M. (2012). Methods for Measuring and Estimating methane emission from Ruminants. *Animals*, www.mdpi.com/journal/animals.

ITA (International Technology Association) (2004). Nigerian livestock. *The Library of Congress Country Studies*; CIA World Fact book. Retrieved from http://www.photius.com/countries/nigeria/economy/nigeria.

Intergovernmental Panel on Climate Change [IPCC] (2007). *Climate Change 2007:* Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the *Intergovernmental Panel on Climate Change,* 104. Geneva,Switzerland,IPCC.
http://www.ipcc.ch/publications and data/publications ipcc fourth assessment report synthesis_report.htm.

Intergovernmental Panel on Climate Change [IPCC] (2013). "Summary for Policymakers," in Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to Assessment Report of the Intergovernmental Panel on Climate Change. New York, NY; Cambridge*: Cambridge University Press*, 1–30.

Irvine, F.R. (1961). Woody plants of Ghana, with special reference to their uses. *Oxford University Press*, London, United Kingdom, 868:687-688.

Isah, O.A., Babayemi, O.J., Yakubu, A. and Adewumi, M.K. (1999). The potential of mango and Gliricidia leaves as protein supplement in the diet of West African dwarf goats. *Tropical Animal Production Investigation*, 2:35-39.

Isah, O.A., Fayemi, P.O., Gazaly, M.B. and Aderinboye, R.Y. (2012). Nutritional characteristics of four browse plants consumed by free-ranging ruminants in Western part of Nigeria. *African Journal of Agricultural Research*, 7(12):1944-1949.

Isah, O.A., Okunade, S.A., Aderinboye, R.Y and Oyekunle, M.A. (2014). Rumen fermentation and microbial profile of red Sokoto goats fed threshed sorghum top supplemented with browse foliages. *Tropical Animal Production Investment,* 17(1):67-73.

Jabbar, M.A. (1994). Evolving crop-livestock farming systems in the humid zone of West Africa. *Journal of Farming Systems Research and Extension,* 4 (3): 47 – 60.

Jentsch, W.; Schweigel, M.; Weissbach, F.; Scholze, H.; Pitroff, W.; Derno, M. (2007). Methane production in cattle calculated by the nutrient composition of the diet. *Arch. Animal Nutrition,* 61:10–19.

Jimoh, F.O. and Oladiji A.T. (2005). Preliminary studies on *Piliostigma thonningii* seeds: Preliminary analysis, mineral composition and phytochemical screening *African Journal of Biotechnology*, 4: 1439-1442.

Johnson, K.A. and Johnson, D.E. (1995). Methane emissions from cattle. *Journal of Animal Science*, 73:2483-2492.

Jose, V.S., Sejian, V., Bagath, M., Ratnakaran, A.P., Lees, A.M., AL-Hosni, Y.A.S., Sullivan, M., Bhaha, R. and Gaughan, J.B. (2016). Modeling of Greenhouse Gas Emission from Livestock Frontiers Environmental Science, 14 April. http://dx.doi.org/10.3389/fenvs.2016.00027.

Kolver, E.S. and de Veth, M.J. (2002). Prediction of ruminal pH from pasture based diets. *Journal of Dairy Science,* 85: 1255- 1266.

Lanyasunya, T.P., Rong, W.H., Abdulrazak, S.A., Kaburu, P.K., Makori, J.O., Onyango, T.A. and Mwangi, D.M. (2006). Factors limiting use of poultry manure as protein supplement for dairy cattle in smallholder farms in Kenya. *International Journal of Poultry Science*, 5: 75-80.

Lemessa, D. (2010). *Piliostigma thonningii* (Schumach.) Milne-Redh. [Internet] Record from PROTA4U. *PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale)*, Wageningen, Netherlands. http://www.prota4u.org/search.asp.

Leng, R.A. (1990). Factors Affecting the Utilization of 'Poor-Quality' Forages by Ruminants Particularly Under Tropical Conditions. *Nutrition Research Reviews*, 3: 277-303.

Leng, R.A. (1997). Tree legumes in ruminants nutrition. *FAO Animal Production and Health* Paper. 139, FAO, Rome.

Le Quéré, C., Moriarty, R., Andrew, R.M., Peters, G.P., Ciais, P., Friedlingstein, P.(2014). Global Carbon Budget 2014. *Earth System Science. Data* 7, 521–610.

Li, X.X., Durmic, Z., Liu, S.M., McSweeney, C.S. and Vercoe, P.E. (2014). *Eremophila glabra* reduces methane production and methanogen populations when fermented in a rusitec. Anaerobe. 29:100–7.10.1016/j.anaerobe.10.008.

Li, Q., Gupta, S., Tang, L., Quinn, S., Atakan, V., and Riman, R.E. (2016). A novel strategy for carbon capture and sequestration by rHLPD Processing. *Frontiers Energy Research* 3:53.

Lock, J.T. and Simpson, M.J. (1999). *Legumes of West Tropical Asia*, 3rd Edition. Academic Press Inc, London, 216-220.

Lunginbuhl, J.M. (2015). Nutritional feeding management of meat goats. NC Cooperative Extension Service.

Machado, L., Magnusson, M., Paul, N.A., Nys, D.R. and Tomkins, N. (2014). Effects of marine and freshwater macroalgae on in vitro total gas and methane production. PLoS One 9:e85289.10.1371/journal.pone.0085289.

Makkar, H.P.S. (2003). Effects and fate of tannins in ruminant animals, adaptation to tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. *Small Ruminant Research,* 49: 241-256.

Mandibaya, W. and Chihora, R.M. (1999). The nutritional value of *Piliostigma thonningii* (Mutukutu, monkey bread) pods as a feed supplement for communal cattle in Zimbabwe. *Animal Feed Science and Technology*, 78(3–4): 287–295.

Marx, T. (2014). Feeding Fats and Oils in Feedlot Diets. *Alberta Agriculture and Forestry*. http://www1.agriculture.alberta.ca/$department/deptdocs.nsf/all/webdoc11806/app21.

Milford, R. and Minson, O.J. (1967). The voluntary and digestibility of diets containing different proportions of legumes and mature Pangela grass. *Australian Journal of Experimental agriculture.* Animal Husbandary, 7:546-551.

Moate, P.J., Williams, S.R.O., Torok, V.A., Hannah, M.C., Ribaux, B.E., Tavendale, M.H. (2014). Grape marc reduces methane emissions when fed to dairy cows. *Journal of Dairy Science*, 97:5073–8710

Morgavi, D.P., Martin, C. and Boudra, H. (2013). Fungal secondary metabolites from *Monascus* spp. reduce rumen methane production *in vitro* and *in vivo*. *Journal of Animal Science,* 91:48–60.

MSU – Mississippi State University Extension Service. (2009). Understanding the Ruminant Animal's Digestive System. The Cattle Site-Cattle Health, Welfare and Diseases New 5m publishing. http://www.thecattlesite.com/images/5mpublishing.jpg.

Muller, A.K., Westergaard, K., Christensen, S. and Sorensen, S.J. *(*2002*)*. The diversity and function of soil microbial communities exposed to different disturbances. *Microbial Ecology*, 44: 49–58.

Mutshinyalo, T. and Sisulu, W. (2010). National Botanical Garden. November R© South Africa National Biodiversity Institute. http:///www.plantzafrica.com.

Neuwinger, H.D. (2000). African traditional medicine: a dictionary of plant use and applications. *Medpharm Scientific*, Stuttgart, Germany, 589.

Ngbede, J., Yakubu, R.A. and Nyam, D.A. (2008). Phytochemical Screening for Active Compounds in *Canarium scheinfurthii* (Atile) leaves from Jos North, Plateau State Nigeria. *Medwell Research Journal of Biological Science*, 3(9): 1076-1078.

Nguyen, S.H., Li, L. and Hegarty, R.S. (2015). Effects of Rumen Protozoa of Brahman Heifers.and Nitrate on Fermentation and *In vitro* Methane Production *Asian-Australasian Journal of Animal Sciences (AJAS)*, 29(6): 807-813.

NRC (1985). Nutritional Requirement of Domestic Animals. Nutrient requirement of Sheep.5th Edition .*National Academy of Sciences- National Research Council*, Washington DC., USA.

Odedire, J.A. and Oloidi, F.F. (2014). Nutritional Performance of West Dwarf (WAD) goats fed wild sunflower (*Tithonia Diversifolia*) leaf meal supplemented diet. Conference on International Research on Food Security, Natural Resources Management and Rural Development organized by the Czech University of Life Sciences Prague. *Tropentag, Prague, Czech Republic* September, 17-19.

Odukoya, O.A. (2002). Herbs, Species and Medicinal Plants. *Nigerian Pharmacology Journal,* 1: 39-40.

Ogbeh, A. (2016). Nigeria releases census of goats, sheep, pigs, other livestock in Country-Premium Times Nigeria. http://www.premiumtimesng.com/news/top-news/204577.

Ogunbosoye, D.O. and Babayemi, O.J. (2010). Potential values of some non-leguminous browse plants as dry season feed for ruminants in Nigeria. *African Journal of Biotechnology,* 9(18):2720 - 2726.

Ogunbosoye, D.O., Tona, G.O. and Otukoya, F.K. (2015). Evaluation of the Nutritive Value of Selected Browse Plant Species in the Southern Guinea Savannah of Nigeria for Feeding to Ruminant Animals. *British Journal of Applied Science & Technology*, 7(4): 386-395.

Okoli, I.C., Ebere, C.S., Uchegbu, M.C., Udah, C.A. and Ibeawuchi, I.I. (2003). A survey of the diversity of plants utilized for small ruminant feeding in Southeastern Nigeria. *Agriculture Ecosystem and Environment*; 96:147-154.

Okoli, I.C., Ogundu, E.C., Achonwa, C.C., Obichili, E., Kubkomawa, H.I. and Okoli, C.G. (2014). Selection of candidate indigenous browse plants for domestication in the rainforest zone of south-eastern Nigeria. *International Journal of Agriculture, Forestry and Fisheries,* 2(5):73-80.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. (2009). Agroforestry Database: a tree reference and selection guide version 4.0 http://www.worldagroforestry.org/sites/treedatabases.asp.

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

Osuji, P.O., Nsahlai, T.V. and Khalili, H. (1993). Feed evaluation. ILCA MANUAL 5. ILCA (International Livestock Center for Africa). Addis Ababa, Ethiopia, 40.

Osuji, P.O., Fernandez-Riviera, S. and Odenyo, A. (1995). Improving Fibre Utilisation and Protein Supply in Animals Fed Poor Quality Roughages. *ILRI Nutrition Research and Plans.* In: Wallace, R.J. and Lahlou-Kassi,A. (Eds.).*Rumen Ecology Research and Planning, Vol. 1*. International Livestock Research Institute, Addis Ababa, 1-22.

Oskoueian, E., Abdullah, N. and Oskoueian, A. (2013). Effects of flavonoids on rumen fermentation activity, methane production, and microbial population. 2:349129.10.1155/349129.

Otaru, S.M. and Iyiola-Tunji, A.O. (2015). Small Ruminant Production And Management Techniques. Paper presented at National Workshop on "Strategies for improving livestock and fisheries extension service delivery for sustainable productivity'' which was held at National Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria from 26th – 28th. . DOI: 10.13140/RG.2.1.1817.8002.

Otesile, E.B., Kasali, O.B. and Nzeku, C.K.N. (1983). Mortality in goats on the University of Ibadan Teaching and Research of Ibadan Teaching and Research Farms, Ibadan, *Nigerian. Bulletin of Animal Health and Production in Africa*, 30: 235 – 239.

Oyenuga, V.A. and Fetuga, B.L. (1975). Some aspects of the biochemistry and nutritive value of the watermelon seed (*Citrullus vulgaris* schrad) *Journal of Food Science and Agriculture*, 26: 843-846.

Ozolua, R.I., Alonge, P. and Igbe, I. (2009). Effects of leaf extracts of Piliostigma thonningii Schum. on aortic ring contractility and bleeding time in rats. *Journal of Herbs, Spices* and *Medicinal Plants,* 15(4): 326–333.

Ozung, P.O., Nsa, E.E., Ebegbulem, V. N. and Ubua, J.A. (2011). The Potentials of Small Ruminant Production in Cross River RainForest Zone Of Nigeria. *Continental Journal of Animal and Veterinary Research*, 3(1): 33 - 37, 201.

Pacheco, A. R., Curtis, M.M., Ritchie, J.M., Munera, D., Waldor, M.K., Moreira, C.G. *and* Sperandio, V. (2012). Fucose sensing regulates bacterial intestinal colonization. *Nature*, 492: 113–117.

Pal ,K., Patra, A.K., Sahoo, A. and Kumawat, P.K. (2015). Evaluation of several tropical tree foliages for methane production potential, degradability and rumen fermentation *in vitro*. *Livestock Science*, 180:98–105.

Patra, A.K. and Saxena, J. (2010). A new perspective on the use of plant secondary metabolites to inhibit methanogenesis in the rumen. *Phytochemistry,*71:119-222.

Patra, A.K. (2012). Estimation of methane and nitrous oxide emissions from Indian livestock. *Journal of Environment Monitor.*14(26):73–84.

Patra, A.K. (2013). The effect of dietary fats on methane emissions, and its other effects on digestibility rumen fermentation and lactation performance in cattle: a meta-analysis. *Livestock Science,* 155:54-244.

Patra , A. K. and Yu, Z. (2013) Effective reduction of enteric methane production by a combination of nitrate and saponin without adverse effect on feed degradability,

fermentation, or bacterial and archaeal communities of the rumen. *Bioresources Technology,* 148:60-352.

Patra, A.K. (2016). Recent Advances in Measurement and Dietary Mitigation of Enteric Methane Emissions in Ruminants. *Frontiers in Veterinary Science*, 3:39.

Pond, W.G., Church, D.C. and Pond, K.K. (1995). *Basic Animal Nutrition and Feeding*. 4th Edition, John Wiley and Sons Publishers, NY., USA, 415-450.

Prasad, R.J., Sourie, S.J., Cherukuri, V.R., Fita, L., and Merera, C.E. (2015). Global warming: genesis, facts and impacts on livestock farming and mitigation strategies. *International Journal of Agriculture innovation Research* 3:1473- 2319.

Quaghebeur, M., Nielsen, P., Horckmans, L., and Mechelen, D. V. (2015). Accelerated carbonation of steel slag compacts: development of high-strength construction Materials. *Frontiers Energy Research* 3:52.

Raghavendra, B. and Osamu, E. (2007). Measurement of Methane Production from Ruminants *Asian-Australasian Journal of Animal Sciences*; 20(8), 1305-1318.

Rinehart, L. (2008). Ruminant nutrition for Graziers. *National Center for Appropriate Technology* (NCAT), *Agriculture Specialist*; 318.

Ruffo, C.K., Birnie, A. and Tengnas, B. (2002). Edible Wild Plants of Tanzania. *Regional Land Management Unit*; Nairobi. ISBN 9966-896-60-0.

Sanon, H.O. (2007). The Importance of Some Sahelian Browse Species as Feed for Goats. Acta Universitatis Agriculturae Sueciae : 84. ISSN 1652-6880.

Sarwatt, S.V., Milang'ha, M.S., Lekule, F.P. and Madalla, N. (2004.) *Moringa oleifera* and cotton seed cake as supplements for small holder dairy cows fed Napier grass. *Livestock Research for Rural Development* , 16-113.

SAS (2001). Statistical Analysis System User's Guide. Version 6.11, SAS Institute, Inc. Cary, NC. USA.

Savadogo, P., Sawadogo, L. and Taiveau, D. (2007). Effect of grazing intensity and prescribed fire on soil physical and hydrological properties and pasture yield in the savanna wood land of Burkina Faso. *Agriculture ecosystems and environment*, 118:80-92.

Sawe, J.J., Tuitoek, J.K., and Ottaro, J.M. (1998). Evaluation of common Tree Leaves or Pods as Supplements for Goats on Range Area of Kenya. *Small Ruminant Research*, 28: 31-37.

Schultes, R.E. and Hofmann, A. (1973). *The Botany and chemistry of Hallucinogens*, Charles C. Thomas, Spring Fields.111-267.

Seigler, D.S. (1998). Plants with saponins and cardiac glycosides. www.lifwe.vinc.edu/ plantbio/363/saponinslides.

Sibanda, H. M. and Ndlovu. L. R. (1992).The value of indigenous browseable tree species in livestock production in *semi*arid communal grazing areas of Zimbabwe. The Complementarity of Feed Resources for Animal Production in Africa Proceedings of the joint feed resources networks workshopheld in Gaborone, Botswana 4-8 March. *Ajrican Feeds Research Network.* (International Livestock Centre for Africa).

Silanikove, N., Gilboa, N., Perevolotsky, A. and Nitsan, Z. (1996). Goats fed tannin-containing leaves do not exhibit toxic syndromes. *Small Ruminant Research,* 21: 195-201.

Simmons, P. and Carol ,E. (2001). *Storey's Guide to Raising Sheep*. North Adams, MA: Storey Publishing *LLC.* ISBN 978-1-58017-262-2.

Singh, W.P., Singh, M. and Petriayak, B.C. (1979). Effect of protein levels on nutrient digestibility and wool production. *Indian Journal of Animal Science,* 49:277-281.

Smith, M.S., Mark, A. and Gerald, K. (1997). *Beginning Shepherd's Manual*, Second Edition. Ames, Lowa State University Press. ISBN 0-8138-2799-X.

Smit, B., Park, A.A. and Gadikota, G. (2014). The grand challenges in carbon capture, utilization, and storage. *Frontiers Energy Research,* 2:55.

Sodipo, O. A., Awanji, M. A., Kolawole, F. B. and Oduntuga, A.A. (1991). Saponin is the active fungal principle in *Garcinia kola*, Hekle seed. *Biological Science Resource Community*, 3:171.

Soetan, K. and Oyewole, O. (2009). The need for adequate processing to reduce the antinutritional factors in plants used as human foods and animal feeds: A review *African Journal of Food Science,* 3(9):223-232.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. and de Haan, C. (2006). Livestock's Long Shadow: Environmental Issues and Options. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. http://www.fao.org/contact-us/terms/en.

Sun, X.Z., Waghorn, G.C., Hoskin, S.O., Harrison, S.J., Muetzel, S. and Pacheco, D. (2012). Methane emissions from sheep fed fresh brassicas (*Brassica* spp.) compared to perennial ryegrass (*Lolium perenne*). *Animal Feed Science Technology*, 176:107–161

Swaminathan, M.S., Jain, H. K. (1973). Food legumes in India Agric. In: Nutritional improvement of food legumes by breeding. Protein Advisory Group, United Nations. New York, 69-82.

Tandon, S. (2005). Phytochemicals and cardiovascular health. *Current R&D Highlights*, 28:18–22.

Tanner, G.J., Moore, A.E. and Larkin, P.J. (1994). Proanthocyanidins Inhibit Hydrolysis of Leaf Proteins by Rumen Microflora in Vitro. *British Journal of Nutrition*, 74: 947-958.

Tan-Wilson, A.L., Anna L.T., Jean ,C.C., Michele, C.D., Cathy, C., Obach, R.S. and Karl, A.W. (1987). "Soybean Bowman-Birk trypsin isoinhibitors: classification and report of a glycine-rich trypsin inhibitor class". *Journal of Agriculture Food Chemistry,* 35 (6):974.

Temple, V.J., Odewumi, L. and Joseph, K. (1991). Soybeans and soybean based diets. In: *Proceedings of the 3rd regional workshop on rural development*, Jos, 31st July – 2nd August, 45-50.

Tbezinda, I.M. and Eik, L.O. (2007). Meat goats and their utilization of browse forage**.** Mbarara Zonal Agricultural Research and Development Institute.P. O. Box 389, Mbarara, Uganda. *Tanzania Journal of Agricultural Science,* 8(2):203-220.

Tona, G.O., Akinlade, J.A., Olabanji, R.O., Onyia, S.U. and Adekiitan, A.B. (2010). Performance and nutrient digestibility of weaned rabbits fed graded levels of *Piliostigma thonningii* leaf meal- based diets. Proceedings of 33rd Annual Conference. *Nigeria Society of Animal Production*, 278- 281.

Tona, G.O. (2011). Chemical composition and nutrient digestibility of *Panicum maximum* and *Piliostigma thonningii* leaves fed to West African Dwarf rams as dry season fed. *Ozean Journal of Applied Sciences,* 4(3):1943 – 2429.

Ugwu, F. M. and Oranye, N. A. (2006). Effects of some processing methods on the toxic components of African breadfruit (*Treculia africana*). *African Journal* of *Biotechnology,* 5:2329-2333.

UMN - University of Minnesota Extension (2017). Ruminant anatomy and physiology. *Regents of the UniversityofMinnesota*.WW00469 http://www.extension.umn.edu/distribution/livestocksystems/components/di0469-02.html.

Van Soest, P.J. (1994). Nutritional ecology of Ruminant. 2nd edition. Cornell University Press, Ithaca, New York.

Venkateshwarlu, G., Sathis, D.K., Sravan, M.P., Vijay, K.B., Gowerishankar, N.L.,Blaskar, J., Dhanalakshmi, C. and Harani, A. (2011). Anti-ulcer activity of leaf extract of *Piliostigma thonningii* in albino rats. *European Journal of Biological Sciences,* 3(1):22-24.

Vergé, X.P.C., Dyer, J.A., Desjardins, R.L. and Worth. D. (2007). Greenhouse gas emissions from the Canadian dairy industry. *Agricultural System*, 94:683–693.

Waghorn, G.C., Tavendale, M.H. and Woodfield, D.R. (2002). Methanogenesis from forages fed to sheep. In: *Proceedings of the New Zealand Society of Animal Production*, 266 – 277.

Wanapat, M., Anusom, C., Kampanat, P. and Sungchhang, K. (2015). Dietary sources and their effects on animal production environmental sustainability. *Journal of Animal Nutrition*, 1(3):96 – 103.

Weaver, S. (2005). Sheep: Small-Scale Sheep keeping for pleasure and profit. 3 burroughs irvine H*obby Farm Press*, 121 -234.

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

Wina, E., Muetzel, S. and Becker, k. (2005). The impact of saponin or saponin containing plant materials on ruminant production- a review of *Journal of Agricultural Food Chemistry*, 53:8093-8105.

Yan, T., Mayne, C.S., Porter, M.G. (2006), Effects of dietary and animal factors on methane production in dairy cows offered grass silage based diets. *International Congress Service. 1293*, 123–126.

Yasuo, K. (2010). Abatement of methane production from Ruminants: Trends in the manipulation of rumen fermentation. *Asian- Australian Journal of Animal Science*, 23(3):410-416.

Yousuf, M.B. and Ogundun, N.J. (2005). Feeding value of shed of fresh Ficus *(Ficus Thonningii)* leaves for the West African Dwarf goat. *Center (Science Edition),* 13(1): 51-59.

Yahya, M.S., Takahash, J., Matsuoka, S., Kibon, A. and Dibal, D.B. (2000). Evaluation of arid region browse species from north eastern Nigeria, using pen fed goats. *Small Ruminant Research*, 79:137- 143.

Yulistiani, D., Jelan, Z. A., Liang, J. B., Yaakub, H., and Abdullah, N. (2015). Effects of supplementation of mulberry (*Morus alba*) foliage and urea-rice bran as fermentable energy and protein sources in Sheep fed urea-treated rice straw based diet. *Asian Australasian Journal of Animal Sciences,* 28(4), 409 – 501.

APPENDICES



Figure 3: *Piliostigma thonningii* plant



Figure 4: *Piliostigma thonningii* leaf



Figure 5: *Piliostigma thonningii* leaf meal



Figure 6: *Piliostigma thonningii* pod



Figure 7: *Piliostigma thonningii* pod meal