EFFECT OF SEQUENCE AND INTERVAL OF FEEDING CONCENTRATE SUPPLEMENT AND ROUGHAGE ON PERFORMANCE OF YANKASA WEANER RAMS

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AHMADU BELLO UNIVERSITY,

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B. AGRIC. (ANIMAL SCIENCE) AHMADU BELLO UNIVERSITY, ZARIA (2009)

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

DEPARTMENT OF ANIMAL SCIENCE,

FACULTY OF AGRICULTURE,

AHMADU BELLO UNIVERSITY,

ZARIA, NIGERIA.

JULY, 2015.

DECLARATION

I hereby declare that this thesis titled **Effect of sequence and interval of feeding concentrate supplement and roughage on performance of Yankasa weaner rams** has been written by me and is a product of research work conducted by me. It has not been accepted in any previous application for higher degree. To the best of my knowledge, this thesis contains no materials previously published or written by another person except where due references have been made in the text.

ADELEKE, RASAQ AJADI

________________________	__________________	_____________
Name of Student	**Signature**	**Date**

CERTIFICATION

This thesis entitled EFFECT OF SEQUENCE AND INTERVAL OF FEEDING CONCENTRATE SUPPLEMENT AND ROUGHAGE ON PERFORMANCE OF

YANKASA WEANER RAMS by ADELEKE Rasaq Ajadi, meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

Prof. C.B.I. Alawa

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Dean, School of Postgraduate Studies (Signature) (Date)

DEDICATION

To my Supervisor, Dr. S.M. Otaru for his relentlessness in making this work a success.

ACKNOWLEDGEMENT

All praise is due to Allah alone, the Cherisher and Sustainer of the worlds. Blessings and peace be upon Muhammad, the mercy of Allah to all creatures, who said: “whoever is not grateful to people is not grateful to Allah”.

I am very appreciative of the guidance, suggestions and immensely useful contributions of Professor C.B.I. Alawa, my major supervisor to the richness of this study. I feel extremely grateful to Dr. S.M. Otaru, my second supervisor for his meritorious kindness towards me and for his invaluable contributions, suggestions and very constructive criticisms which unquestionably enriched the quality of this study. Indeed, I owe him a great debt of gratitude.

I am also grateful to Dr. S.B. Abdu for his interest and concern for the progress of my work and his useful pieces of advice. I wish to thank Professors O.S. Lamidi, J.T. Amodu, O.W. Ehoche, C.A.M. Lakpini and A.I. Adeyinka, Dr. A. Giwa, Dr. D.D. Dung, Dr. M. Kabir, Dr S. Duru, Dr. J.M. Hussaina, and all lecturers of Department of Animal Science, Faculty of Agriculture, Ahmadu Bello University, Zaria, for their individual contributions.

I acknowledge with appreciations the assistance given to me by the staff of Small Ruminant Research Programme during the feeding and metabolism trials of this study, such as Messrs Muhammad Iliya, Abdullahi, Jerry Luka, Didam Tabat and Hashim. I am also grateful to the staff of the Central Laboratory of the National Animal Production Research Institute for their assistance in the chemical analyses of samples. I am extremely thankful to the management of the National Animal Production Research Institute for providing the animals, feeds and facilities to conduct this research.

My profound gratitude goes to my landlord, Mr. Adeleke Abdulkadir Mustafa, and his wife Mrs. Mutiat Lawal for their support and kindness. I am also very appreciative of the efforts of my friends, such as Messrs Umaru Muhammad Ahmad, Alabi Isah Idowu, Badmus

Kaszim Ajasa, Olalekan Ismail, Imam Shittu Yusuf (Late), Adebayo Ishaq, Sa’eed Kakako, Muhyideen Ajala, Gbemisola Rahman, Dr. Arojuraye Soliu, and Dr. Adesope Sa’eed.

I m deeply indebted to my uncle, Alhajj Haamid Gbodo and my mother, Mrs. Sa’aadat Apinke Fasaasi for their continuous moral and financial support since my childhood and throughout my study. I am also much obliged to my father, Alhajj Yunus Ajagbe, my uncle, Alhajj Ibrahim Gbodo, my brothers, Adewale Sulyman, Adebayo Abdullah, Kamaldeen Oke, Mubarak Folohunsho, and my dear sister, Kafayat Aduke for their moral support.

Finally, I am very grateful to Allah who made this study conclusive, because I almost lost the hope of it been completed.

ABSTRACT

A feeding trial lasting 90 days was conducted using 28 Yankasa weaner rams with an average weight of 14.96 ± 1.10 kg (5-6 months old) to investigate effect of sequence and feeding interval of concentrate supplement (CS) and roughage on performance. The animals were randomly assigned to four treatments (T1: CS fed 1 h prior to feeding grass hay; T2: CS fed 2 h prior to feeding grass hay; T3: grass hay fed 1 h before feeding CS; and T4: grass hay fed 2 h before feeding CS) using a 2x2 factorial arrangement in a randomized complete block design (RCBD). The animals were fed Wooly finger grass (*Digitaria smutsii* Stent) hay and CS at the rate of 2.4% and 1.6% of body weight, respectively, and offered water *ad libitum*. Blood collection was done every 4 wk before feeding and 4 h after second feeding. Rumen fluid was collected before feeding and 3 h after second feeding during the last week of feeding trial. Thereafter metabolism trial was conducted with 20 of the rams. Animals in treatment 2 had greater dry matter intake ($P < 0.05$) than animals in treatment 1, but statistically similar in dry matter intake to those in treatments 3 and 4. The total weight change of treatment 4 animals was significantly ($P < 0.05$) higher than those of treatment 1 animals, but statistically similar to weight change of treatment 2 and 3 animals. Differences in average daily gain (ADG) among treatments were not significant ($P > 0.05$). Total volatile fatty acids and pH values of the rumen of the rams 3 h post-feeding were affected ($P < 0.05$) by the interval of feeding. Blood creatinine levels 4 h post-feeding were only significantly ($P < 0.05$) affected by interval of feeding grass hay and CS. Apparent digestibility of dry matter (DM) and organic matter (OM) was higher in treatment 4 animals, although no significant ($P > 0.05$) differences among treatments. Nitrogen intake and retention were not significantly ($P > 0.05$) different among treatments. It is concluded that, even though, feed intake and growth rate of Yankasa rams were not markedly affected by the sequence (of feeding) as much as interval of feeding CS and grass hay, the rams in treatment 4 had better feed efficiency and nutrient digestibility for better

feed utilization and improved performance. Yankasa rams can be fed grass hay 2 h before feeding concentrate supplement.

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ABBREVIATIONS

ADF = Acid detergent fibre

ADG = Average daily gain

ATP = Adenosine triphosphate

BUN = Blood urea nitrogen

BW = Body weight

CF = Crude fibre

CP = Crude protein

CS = Concentrate supplement

CSC = Cottonseed cake

d = Day

DDMI = Daily dry matter intake

dl = decilitre

DM = Dry matter

EE = Ether extract

EMS = Efficiency of microbial synthesis

FCR = Fibrous crop residues

g = Gramme

GE = Gross energy

GHG = Green house gas

h = Hour

HZWA = Humid Zone of West Africa

Kg = Kilogramme

l = litre

LCFAs = Long chain fatty acids

ME = Metabolisable energy

mg = Milligramme

min = Minute

MJ = Mega joule

ml = millilitre

mmol = millimole

MNBL = Multi-nutrient block licks

MPS = Microbial protein synthesis

MW = Metabolic liveweight

N = Nitrogen

NDF = Neutral detergent fibre (NDF)

NDSF = Neutral detergent soluble fibre

NPN = Non-protein nitrogen

NSC = Non-structural carbohydrate

OL = Oak leaves

OM = Organic matter

OMD = Organic matter degradability

P = Protein

P/E = Protein: energy ratio

RDN = Rumen degradable nitrogen

RUP = Ruminally undegradable protein

SSA = Sub-Saharan Africa

TMR = Total mixed rations

µmol = micromole

VFAs = Volatile fatty acids

VFI = Voluntary Feed Intake

VI = Voluntary intake

WAD = West African Dwarf

WM = Wheat middling

WS = Wheat straw

CHAPTER ONE

INTRODUCTION

Sheep and goats are domestic animals that have been associating with humans for a very long time. In traditional setting, they serve as means of ready cash and a reserve against economic and agricultural production hardship (Hamito, 2008). They play a significant role in the food chain and overall livelihoods of rural households, where they are largely the property of women and their children (Lebbie, 2004). They are good producers of meat for human consumption. The short gestation interval of sheep and goats and the absence of religious bias against their meat (Ozung *et al*., 2011) are among the reasons why they are kept by peoples of various cultures, religions and races. In the developed countries where consumers are conscious of fat intake, a situation which results into cardio-vascular diseases, goat meat (chevon) with comparatively low amount of intramuscular fat are preferred to beef and/or mutton. It has been reported that there is now a niche market for chevon in US (Luginbuhl, 2000; Coffey, 2006; Okpebholo and Kahan, 2007).

Productivity of small ruminants in many tropical areas is often poor because they are subjected to various kinds of diseases, feeding and housing management techniques. Several survey reports (Devendra and Burns, 1983; Okorie and Sanda, 1992; Ademosun, 1994; Aliyu *et al*., 2005; Shiawoya and Tsado, 2011) indicated that small holder farmers that own over 70% of the livestock population in sub-Saharan Africa offer their stocks little or no supplementary feed. Yet because of low nutrient quality, pasture alone and more specifically tropical grasses cannot provide growing animals sufficient amount of energy intake to attain appropriate growth rate for higher slaughter weight and dressing percentage (Humphreys, 1991). Several works had shown that young animals raised on forages alone had lower daily gains, dressing percentage and carcass quality than those supplemented with concentrate (Warmington and Kirton 1990; Johnson and McGowan 1998; Kosum *et al*., 2003; Johson *et al*., 2005). Concentrate feeds promote rapid growth of sheep and cattle (McDonald *et al*.,1996), increase propionate production and reduce ruminal methane production, thereby lowering energy losses and contributing to higher overall efficiency of utilization of dietary energy for body weight gain (Mandebvu and Galbraith, 1999). According to Mtenga and Kitalyi (1990) increase in meat output resulting from concentrate supplementation can improve access to animal protein and income to households in the traditional sector.

With respect to milk production, Kolver *et al*. (1998) opined that supplementation with concentrates is a viable option to enhance milk production in lactating dairy cows under grazing conditions. Increase in level of dietary concentrate was observed to cause increase in milk production in ewes (Avondo *et al*., 1995; Zervas *et al*., 1999) and Red Sokoto goats (Otaru, 2009). However, high levels of concentrate feeding can cause low ruminal pH (Mould *et al*., 1983; Carro *et al*., 2000), which can decrease forage degradability (Mould *et al.*, 1983; Allen, 1997) and induce clinical ruminal acidosis. The appropriate ratio of concentrate to roughage to be fed to ruminants had been studied (Zervas *et al*., 1999). A ratio of 40:60% concentrate to hay had been recommended (Liu *et al*., 2005). Concentrate supplements by nature are more easily degraded than roughages. Consequently, concentrate supplements fed before feeding roughage degrade rapidly and lower the rumen pH before the buffering effect of roughage fermentation, which occurs afterwards, sets in.

According to Smith (1992), feed constraints currently limiting small ruminant production and productivity in humid West Africa were, to a large extent, due to a non-strategic utilization and combination of available feed resources, to develop production feeding system, rather than absolute quantitative and qualitative shortages. It is a common practice that farmers, under semi-intensive system in the forest belt of humid West Africa, offer feed supplements to their animals first thing in the morning before turning them out to graze fibrous grasses all day. However, results of rumen degradability studies suggested that this system should be the other way round, with the rapidly degraded feeds fed late in the afternoon and at night, to better synchronize the release of the energy and nitrogen they contain with those of the less rapidly degraded grasses. There is a need to verify this premise on-farm (Smith, 1992).

Feeding of concentrate supplements subsequent to feeding roughage had been suggested to enhance higher intake of roughages, and increase productivity of animals (Robinson, 1989; Beauchemin, 1992). Nevertheless, work by Robinson (1994) showed that changing the sequence of feeding supplemental grain relative to forage-based mixed ration did not improve or modify the productivity of primiparous cows. Many of the experiments conducted to investigate the influence of changing the sequence of feeding concentrate supplements and roughages on the performance of ruminants either fed supplement 1 h (Robinson, 1994; Carro, 1994) or less than 1 h (Morita and Nishino, 1993; Zeyner *et al*., 2004) before or after feeding the roughage. The time intervals were probably too short for effective degradation of basal ration; hence there is a need for extended time intervals. In addition, there is paucity of information on similar studies with our indigenous small ruminants using the compounded concentrate supplement.

Therefore, this study was designed to evaluate the effects of changing the sequence of feeding concentrate supplement and grass hay on performance of Yankasa weaner rams.

The objectives of this study were to:

i. Determine the appropriate time interval for feeding concentrate supplement relative to grass hay.
ii. Determine the effect of the sequence and feeding interval of concentrate supplement and grass hay on feed intake, digestibility of nutrients, and growth of Yankasa weaner rams.

HYPOTHESIS

Ho: The sequence and interval of feeding concentrate supplement and grass hay will not have effect on intake and performance of Yankasa weaner rams.

H_A: The sequence and interval of feeding concentrate supplement and grass hay will have effect on intake and performance of Yankasa weaner rams.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 IMPORTANCE OF SMALL RUMINANTS IN NIGERIA

Sheep and goats are typical cloven-hoofed ruminants of relatively small size collectively referred as small ruminants (Egahi *et al*., 2012). Ruminant animals are recognized to be among the least tolerant to heat stress, which is caused by one or a combination of environmental factors such as ambient temperatures, relative humidity, solar radiation, and air movement (Uyeno *et al*., 2010). Ruminant animals help in turning nutrients in the waste into animal products for human use especially when they are fed with poultry litter (Jordaan, 2004). Small ruminants remain popular among the rural populace and resource-poor people. Their importance is primarily associated with their small size, which is of significant advantage for mankind as it favours low investments and minimal risk of loss. Their preference over large ruminants for food, reproductive efficiency and economic use of available marginal land is noteworthy (Omoike, 2006). They have long constituted an integral part of traditional crop-livestock production systems in Sub-Saharan Africa.

Raising small ruminants (sheep and goat) is an important economic activity from which food (meat, milk) and non-food commodities (manure, hides and skins, wool, etc) and cash income are derived. Meat is one of the most important small ruminant products (Seyoum, 1992). Sheep and goat milk is essential as a source of high quality protein and Ca in arid areas, especially for starving or malnourished people, where cattle have difficulties to be maintained (Zervas and Tsiplakou, 2011). The quantities of sheep and goat milk produced represents 1.3% and 2.1% of the total world's milk production, respectively, with the commercial dairy sheep being concentrated in the Europe and the countries on or near the Mediterranean basin (FAO, 2007). Furthermore, Hooft *et al.* (2008) stated that small ruminants play risk mitigation, cultural, religious and social roles.

In Nigeria, sheep are kept primarily for meat production. They contribute about 11% of the total meat supply in the country (Adu and Ngere, 1979). Meat constitutes the foremost animal product that is highly explored by the Nigerian households, particularly for direct consumption and as such, the ruminants, especially cattle, constitute the major and cheapest source of meat consumption for most households in the country. Although the small ruminants, especially goats, are as well slaughtered for meat sale, the small size of the animals and high market price of their meats make the animals less demanded for regular meat consumption. However live goats and sheep are much more easily acquired by individuals in relation to cattle owing to market price differentials between the small and large ruminants (Lawal-Adebowale, 2012).

The total world population of 1024 million sheep and 768 million goats are found mainly in developing countries. Asia and Africa together account for as much as 64.5% and 91.5% of the total world's sheep and goats population, respectively, while the respective figures for Oceania and Europe together is 27% and 2.4% (FAO, 2007). It was reported that Nigeria had a population of 56,524,100 goats, 33,519,800 sheep, 16,578,000 cattle, 7,471,730 pigs and 192,313,000 chickens (FAO, 2012).

Umeh (2004), using an assumed growth rate of 2.4% and off-take rate of 25%, projected that in the year 2015 Nigerian population of sheep and goats would be

39,991,693 and 63,951,802, respectively, with corresponding meat production of 1,499,688 and 15,987,951 tonnes.

Livestock, especially ruminants, are important contributors to the amount of the Green House Gas (GHG) emissions from agriculture into the atmosphere (FAO, 2006). The possible environmental pollutants produced by livestock are nitrogen, phosphorus and other organic compounds (e.g., methane and nitrous oxide) (Yang *et al.*, 2010). The amounts of nitrogen excreted in animal manure have increased markedly during the last 2 or 3 decades, causing unacceptable air and water pollution (Hristov and Pfeffer, 2005). Major contribution (37% of global anthropogenic methane) of greenhouse gases comes from methanogenesis during fermentation of feeds in the rumen (FAO, 2006). The types of management systems employed in rearing livestock or in livestock production play an important role in reducing or increasing GHG emissions from the agricultural sector (Aby, *et al.*, 2013). A number of studies (Beauchemin *et al.*, 2008; Martin *et al.*, 2010 and Patra, 2012 cited by Patra, 2013) have focused on exploring technologies and policies for the mitigation of enteric methane emissions in ruminants. Perhaps, due to lack of appropriate facilities, the amount of contribution to methane production by our ruminant animals has not been documented.

2.1.1 Breeds of Sheep, Population and Distribution in Nigeria

According to Nuru (1985), Nigeria had the highest number of goats (52%) in the West African sub-region, but second to Sahel countries only in the production of sheep and goats. Sheep population in Nigeria was estimated (FAO, 2012 cited by Suberu *et al.*, 2013) to be 33.52 million. Sheep and goats are widely distributed in Nigeria in rural, urban and peri-urban areas representing about 63.7% of total grazing domestic animals in Nigeria (Gefu, 2002). Sheep are the second most numerous pastoral species in Nigeria, and small flocks often accompany many cattle herds in the north and in the Middle-Belt (Ugwu, 2007). The highest sheep population was recorded in the North West zone, where Kano State has the largest population of about 2.6 million heads and Zamfara recording the lowest sheep population of about 857,000 heads. The South West zone had about 1.1 million heads of sheep with Edo State having the highest population of 668,410 heads (FMARD, 2002).

There are four main breeds of sheep indigenous to Nigeria: They are the Balami, Uda, Yankasa, and West African Dwarf (WAD) sheep. Out of these four breeds of sheep, the WAD breed is mainly found in the southern region of the country. The Balami and Uda are predominant, respectively in the north-eastern and north-western parts of the country, where they thrive and survive better (Lawal-Adebowale, 2012). Yankasa breed is the most numerous and widespread in the country, constituting about 50 - 60 % of the national population (Osinowo *et al*., 1992). According to Aganga *et al* (1988), Yankasa breed has been the most extensively studied in Nigeria. The coat colour is white with black patches around the eyes and sometimes on the feet. The muzzle and ears are usually black too. Ewes are polled, but the rams have curved horns and hairy white mane. In the wet season, Yankasa sheep do not need daily watering and once-a-day watering suffices in the dry season. Osinowo *et al* (1992) observed that pre-weaning growth performance of Yankasa sheep was generally better in the wet season than in the dry season while the reverse was true for weaning rate. The authors recorded a birth weight of 2.51 ± 0.01 kg, 90-day weaning weight of 10.87 ± 0.08 kg, average daily gain to weaning of 91.86 ± 0.91 g/d, and weaning rate of 77.8 ± 1.0%. And further observed that dam parity, litter size, month and year of birth significantly affect the birth weight, weaning weight and average daily gain of Yankasa lambs, but sex does not. It was reported (Adewumi and Olorunnisomo, 2009) that Yankasa ewes produce more milk (307.7 ml) than West African Dwarf (WAD) ewes (239.8 ml) when body weight is not considered, but WAD sheep produce more milk (11.5 ml/kg) per kilogram of body weight than the Yankasa (10.5 ml/kg).

2.1.2 Factors Affecting Productivity of Small Ruminants in Nigeria

The Productivity of ruminants is dependent on the potential of a feed to supply, through effective microbial degradation, balanced nutrients for production. Digestible dry matter intake is highly correlated with animal productivity offered individual feeds (Devendra, 1996). Voluntary Feed Intake (VFI) is the single most important factor affecting production in animals and is also associated with digestibility of the feed, and proportion of the digested material that's absorbed (Devendra, 1996). According to ILRI (1995) during a global consultation to define the priority for livestock research, feeding and nutrition was identified as the major constraint to productivity of the animals.

Goats and sheep rearing in the Mediterranean and Tropical environments, including Nigeria, have been hampered over the years primarily by the seasonal non-availability of good quality feeds which results into weight losses, low birth weights, lowered resistance to diseases, and reduced animal performance (Onwuka *et al*., 1989; Winrock international, 1992; Ademosun, 1994; Almeida *et al*., 2007). Several survey reports (Okorie and Sanda, 1992; Aliyu *et al*., 2005; Shiawoya and Tsado, 2011) had indicated that supplementary feeding is rarely practiced by most small ruminant farmers because of the high cost of supplementary feed ingredients. The resulting preference for extensive and semi-intensive systems of management (Lawal-Adebowale, 2012), is however fraught with some problems (e.g. energy deficit) that affect efficient productivity of sheep and goats (Mohgoub and Lu, 2004; Bushara *et al.*, 2010).

The finding of Aphunu and Okoedo (2011), who investigated small ruminants production constraints in Delta state, was in line with Williams and Williams (1991) assertion that the Livestock Extension Service of the Agricultural Development Programmes (ADPs) is generally poorly organized and in some cases non–existent. The authors' findings also confirmed the assertions made by Omoike (2006) that the major problems of sheep and goats rearing include among other things, the inadequate supply of water and pasture especially in the dry season, as well as problems arising from inadequate veterinary services and infrastructure. Kagira and Kanyari (2001) reported that among several constraints that limit productivity of livestock, diseases and parasites are of major importance. Parasitic gastroenteritis has been noted as major constraint to ruminants' productivity in terms of pathology and economic importance (Biu *et al*., 2009). Clarence *et al*. (1991) also reported that lameness due to diseased condition results in significant reduction in productivity of the livestock. Locomotory soundness is a requirement for effective grazing and reproductive performance in all classes of livestock (Egwu *et al.*, 1994).

According to Ademosun (1994), small ruminant breeds in tropical Africa are characterized by small birth weights, low milk production, slow growth rates and small mature weights. However, it was observed (Rege, 1994) that there has been a tendency to over-emphasize the low productivity of indigenous breeds of small ruminants without due consideration of some important characteristics of these breeds, and that when their small size and the harsh environment under which they are raised are taken into account, their productivity is impressive. The author argued that, indeed, the high-performing temperate breeds cannot survive under traditional management in most African environments. Crossbreeding of exotic breeds with indigenous ones is a strategy that will take the advantage of breed complementarily and/or upgrading to allow gradual improvement in productivity.

2.2 FEED RESOURCES FOR SMALL RUMINANTS

2.2.1 Cereals, legumes and fodder crops

Feed resources are the central components and drivers of production systems. The efficiency of use of the available feed resources is especially important as it is the primary determinant of animal performance and productivity (Devendra and Leng, 2011). Fodder resources (cereals, legumes and fibrous crop residues) in warm climates provide the principal sources of feeds for ruminants (Devendra, 1996). Ruminant livestock survival in Nigeria has depended largely on the extensive native pastures, browses and farm crop residues across and within the various agro-ecological zones (Shiawoya and Tsado, 2011; Aruwayo and Maigandi, 2013). Traditional farmers in the semi-arid region of Nigeria allow their goats, sheep and cattle to browse on tree forages, in the range lands and they also cut and feed these tree foliages as supplements based on experience and convenience (Njidda, 2010).

2.2.2 Sugar Beet and Citrus Pulps

In China, some ingredients such as sugar beet and citrus pulps are widely used as sources of energy for ruminant animals. These ingredients are either fed sole or mixed with molasses (Onwuka *et al.*, 1997; Zhao *et al.*, 2013). Most of these ingredients have high content of neutral detergent soluble fibre (NDSF; largely pectin substances) and sugars. In addition, Molasses and urea are known as sources of readily available energy and nitrogen, respectively, used in feeding ruminants (Preston and Leng, 1987). For example, Salem *et al*. (2013) investigated the addition of urea, molasses or mixture of both to ensiled fodder trees' forage. They observed increased metabolisable energy (ME), organic matter degradability (OMD), as well as increased gas production (GP) when molasses was added, and suggested that addition of molasses to forage from fodder trees might improve nutrient utilization in ruminants. Increased flow of microbial crude protein to the small intestine and higher efficiency of microbial synthesis (EMS) were observed (Huhtanen, 1988) when molasses was supplemented to cattle fed grass silage. However, it was found (Hemingway *et al*., 1986) that dried molassed sugar-beet pulp, containing either 200 or 400 g of molasses per kg, did not affect either milk yield or milk components when given to cows receiving grass silage and hay.

2.2.3 Lignocellulosic Agricultural By-products

In tropical countries of the world, the ruminants are fed on lignocellulosic agricultural by-products like cereal straws, stovers, sugarcane bagasse and tree foliages, and cakes of oil seeds like groundnut, cotton, mohua, neem and mustard (Kamra, 2005). Cassava and maize leaves have also been found to be valuable feed materials for ruminants, meeting the nutritional requirements for growth, reproduction and maintenance of ruminants year round (Wanapat *et al*., 2000). Cassava leaves can be fed in mixture with maize leaves and can be used in the diet mixtures of up to 75% of DM fed. This was found to improve feed intake, nutrient digestibility and N utilization leading to a better weight gain in sheep. Therefore, cassava and maize leaves which are otherwise waste materials can be used as substitute to hay in the seasons when grass forage supply is scarce, especially in the smallholder sheep production system (Fasae *et al*., 2012).

2.2.4 Wheat Middling

These are by-products from wheat milling and are used as feed for animals. They consist mostly of wheat pericarp, germ, and a small amount of endosperm tissue from various mill streams including the bran, shorts, germ and flour streams (Reed *et al*., 2006). Tufarelli *et al*. (2011) in trial fed a diet containing 600 g/kg dry matter of wheat middling (WM) as total mixed rations for lambs and observed improvement in final live weight and gain, feed conversion ratio, slaughter weight and cold-carcass dressing, and concluded that WM maintained lamb performance and had no negative effect on lamb performance and carcass traits.

Fodder trees and shrubs constitute an important feed resource in harsh environments with long dry periods, because they provide forage for grazing ruminants throughout the year or at specific critical periods of the year, particularly when herbage is scarce or when the quantity and quality of herbaceous species sharply decline (Devendra, 1990). The use of fodder trees and shrubs to ameliorate problems of inadequate feed supply in small ruminant production has long received research attention (Paterson *et al*., 1999; Aregheore, 2004). Some indigenous species have been selected to serve as supplements to the low quality forage fed to animals (Pezo *et al*., 1990). Adegun *et al*. (2011) reported that most trials in the Humid Zone of West Africa (HZWA) conducted by the International Institute for Tropical Agriculture (IITA) and the International Livestock Centre for Africa (ILCA), now International Livestock Research Institute (ILRI), involved *Gliricidia sepium* and

Leucaena leucocephela which have shown benefits to crop production and animal improvement through alley farming and feed gardens. For instance, Ademosun *et al*. (1985) reported an improved daily dry matter intake (DDMI, 42.3 g/kg0.75/d), and significantly higher growth rates (36.0 g/d), when WAD goats were fed *Gliricidia* supplemented with *Leucaena*, than when only *Gliricidia* was fed (37.9 g/kg0.75/d and 23.3 g/d, respectively), with the latter being similar to those reported for goats at village level. However, these species may have limitations in terms of productivity, palatability, presence of toxic substances (e.g. tannins) and adaptability (Akingbamijo *et al*., 2006), and also, the reluctance of smallholder farmers to adopt these tree species as supplements for small ruminant nutrition (Adegun *et al*., 2011). In spite of being an excellent source of nutrients, a number of toxic constituents which severely limit livestock performance are contained in *Gliricidia* (e.g. *Coumarine, O-coumaric acid, hydrochloric acid and tannin*) and *Leucaena* (e.g. *mimosine, phytin and tannin*) (Manoji and Samiran, 2007; Aye, 2012; Chisowa and Mwenya, 2013).

There are many agricultural crop residues [e.g. maize, wheat, rice, sorghum, millet and barley (straw), maize, millet and sorghum (stover), maize cob, sorghum panicle, cowpea (husk and hay), cowpea and groundnut (shell, and haulm), e.t.c.] with great potentials for ruminant animal feeding (Bello and Tsado, 2013). Others include sugar cane tops, bagasse, cocoa pod husks, pineapple waste and coffee seed pod pulp, all of which are generally produced with high biomass in humid and sub-humid regions (Devendra, 1996). They have been used mostly as roughage for cattle, sheep, goats and horses (Alawa and Umunna, 1993). According to Lufadeju (1988), over 111.5 million tons of crop residues are produced annually in Nigeria.

Fibrous crop residues (FCR) form the main base in feeding systems throughout countries with warm climates (Devendra, 1996). Sibanda and Said (1993) cited by Otaru *et al*. (2011) also reported that crop residues and agro-industrial by-products constitute the bulk of ruminants' diets in developing countries and they are limiting in the nutrients such as amino acids, long chain fatty acids (LCFAs) and glucogenic precursors required by the animals.

In the northern grassland ecology of Nigeria, pastoralists use significant quantities of crop residue while their livestock return manure to the soil. Small-scale ammonification treatment of maize and sorghum stovers known as CRUPROCESS is being extended to farmers in Kano to improve the feeding quality of the straw (Onwuka *et al*. 1997). Large scale use of crop residues is not common in southern part of Nigeria, due to low level of livestock husbandry, even though a lot of crop residues are being generated from cropping and from households (Onwuka *et al*. 1997).

2.3 FORAGE RESOURCES IN NIGERIA

Forage and fodder crops include pasture and range vegetation, as well as crop residues derived from farm crops. Nigeria has a land area of 92.4 million hectares of which about 44% constitutes rangeland or natural pasture, which support its domestic ruminants of over 101 million (FMAWR, 2008; Shiawoya and Tsado, 2011). Shiawoya and Tsado (2011) observed that forage and fodder crops production is a very important component of Nigeria's farming systems, not only from the perspective of cereal and pulses production for human consumption, but also from the perspective of providing adequate feed for the livestock sub-sector of the economy. Some of the important forage species in various agro-ecological zones in Nigeria include: *Andropogon gayanus* (Gamba grass), *Cenchrus ciliaris* (Buffel grass), *Pennisetum pedicellatum* (Kyasuwa), *Digitaria decumbens* (Pangola grass), *Digitaria smutsii* (Woolly finger grass), *Setaria sphacellata* (Golden blue grass), *Panicum maximum* (Guinea grass) and *Pennisetum purpureum* (Elephant grass). These grasses which are fibrous in nature are rich in cellulose and provide the ruminants with high level of structural carbohydrate and some measures of vitamins and minerals (Kallah, 2004).

Important browse plants common across the agro-ecological zones in Nigeria include: *Cajanus cajan* (Pigeon pea), *Butyrospermum paradoxum* (Shea butter tree), *Gliricidia sepium* (Almond blossom), *Gmelina arborea* (Gmelina), *Ficus thoningii* (Ficus), *Zizyphus mauritiana*, *Hibiscus rosa-sinensis* (Chinese hibiscus), *Acacia albida* (Ana tree), *Acacia seyal* (Shitting wood) etc. (Shiawoya, 2006). For instance, significant increases were found in intake and digestibility of barley straw fed to sheep when dried Gliricidia and *Calliandra calothyrsus* were offered as supplements (Ahn, 1990). Otaru (1998) investigated the effects of replacing fresh gamba grass with wilted Ficus leaves in the diet of Red Sokoto bucks, and concluded that *Ficus thoningii* leaves could be included in the diets of goat up to 30% without any adverse effects on intake, digestibility of nutrients and growth. Inclusion of *Zizyphus mauritiana* leaf meal in the concentrate diets of Yankasa ram lambs at 10-20% inclusion levels was found to produce best result in terms of performance than when the leaf meal was fed at higher levels of inclusion to ram lambs (Abdu *et al*., 2012).

Given the distinct nature of the ruminants' stomach, the farm animals heavily depend on forage or roughage as major feeds. Forage availability problems can limit herbivore populations, and affect foraging behavior and growth rates (Therrien *et al*., 2008). Reduced foraging time can limit energy gained by an animal, adversely affecting body condition and subsequent reproductive success (Belant *et al*., 2006 cited by Severud *et al*. 2013). Forages are a vital part of total mixed rations (TMR) for dairy cattle providing them with physically effective fibre (e.g. forage particle size) needed to maintain proper rumen health and functioning. A fine particle size may adversely affect stratification of ruminal digesta, providing fewer stimuli for chewing activity and ruminal contractions (Mertens, 1997), which may result in a reduced ruminal pH, depressed fibre digestion and feed intake as well as lowered feed efficiency (Tafaj *et al*., 2007). In addition, the use of higher proportions of high-quality forages in the diet of dairy cows can help in maintaining high digestible energy intake of the cows despite decreasing concentrate inclusion level, plus the associated cost of feeding (Zebeli *et al*., 2010). Maize silage and grass silage are conserved forages mostly used in the feeding of dairy cows in many parts of the world. They are fed as single forage components, or together, depending mainly on the region, availability, and feeding purpose (Zebeli *et al*., 2010).

2.3.1 Limitations of Forage Feed Resources

Forage digestibility in ruminants is constrained by the extent of cell wall neutral detergent fibre (NDF) digestion (Van Soest, 1994). Another cell wall component, lignin, is generally accepted as the primary component responsible for limiting the digestion of forages (Traxler *et al*., 1998). In tropical regions like Nigeria with two different seasons, the quality of grass changes with seasons. For example during the rainy season tropical forages under grazing have good quality, in the dry season its nutritive value is severely reduced, with increased lignin content in the cell wall and a decreased total content of nitrogenous compounds. These modifications can compromise the availability of energy from forage (Paulino *et al*., 2006) by reducing the neutral detergent soluble compounds and decreasing neutral detergent fibre (NDF) digestibility (Van Soest, 1994 cited by Detmann *et al*. (2009). Low-quality tropical forages are deficient not only in nutrients for animal performance, but also in substrates (e.g. nitrogen) for microbial metabolism (Detmann *et al*., 2009).

The nutrition of sheep in tropical and sub-tropical countries is mainly based on low-quality crop residues and natural pastures. Most of the roughages in these regions are deficient in crude protein, metabolizable energy and some minerals (Ash, 1990 cited by Patra, 2009). Adamu *et al* (1993) showed that the CP content of the native grasses during the dry season is about 1.5 to 3%. This is below the minimum of 7% CP required in forages to enhance voluntary intake, digestibility and utilization by ruminants (Smith, 1993). Crop residues are characterized by high content of fibre usually above 40%, low content of nitrogen (0.3-1.0%) and low content of essential minerals such as Sodium (Na), phosphorus (P) and Calcium (Ca), which result in reduced feed intake and low performance by the ruminant animals (Adegbola, 1998).

Leguminous trees and shrubs often have thorns, fibrous foliage and growth habits which protect the crown of the tree from defoliation. Many plants also produce chemicals which are not directly involved in the process of plant growth (secondary compounds) but act as deterrents to insects and fungal attack. These compounds also affect animals and the nutritive value of the forages. Mycotoxins (fungal metabolites) produced by saprophytic and endophytic fungi are also a potential source of toxins in forages (Norton, 1994). The utilization of the browse is limited by the high lignin content and the presence of anti-nutritional factor which may be toxic to ruminants (Njidda, 2010).

Feeding of forages alone does not support full expression of genetic potentials of ruminant animals. From an experiment conducted by Singh *et al*. (2011) to evaluate the effect of feeding crop residues of cereals and legumes on weight gain of Yankasa rams, it was concluded that feeding the residues of cereals alone resulted in a mean weight loss of 14% for sorghum, 16% for maize and 11% for millet, while feeding the residues of cowpea or groundnut alone resulted in the weight gain of about 13 and 12%, respectively. Researchers (Alhassan *et al*., 1984; Alhassan, 1985; Bello and Tsado, 2013) who fed Sorghum Stover to sheep and goats suggested supplementation with a minimum of 60 g of cottonseed cake (CSC head / day) for sheep and 50 g/ head/ day for goats to reduce weight losses.

2.4 FEED SUPPLEMENTS

The availability of supplements is an important prerequisite in enhancing the utilization of fibrous crop residues irrespective of whether these are treated or untreated with alkali to improve digestibility and voluntary feed intake (Devendra, 1996). Bowman and Sanson (1996) defined supplements as feedstuffs added to the basal diet to provide nutrients required to support the desired level of production. To meet the nutritional needs of ruminants, supplemental CP is often provided to increase forage intake (Lintzenich *et al*., 1995), DM digestibility (Delcurto *et al*., 1990), and body weight (BW) gain (Bodine *et al*., 2001). Supplementation of crop residues with rumen degradable nitrogen (RDN) is necessary in order to meet the protein requirement of rumen microbes for microbial growth and optimum rumen fermentation, and digestion of crop residue based diets. The efficiency with which the RDN in diet is converted to microbial protein, determines the overall efficiency of ruminant diet on one hand and loss of nitrogen in the urine on the other (Chen *et al.*, 1999). Olson *et al*. (1999) and Mathis *et al*. (2000) have well established that supplementation of low-quality forages with concentrate supplements can boost intake of low-quality forages, enhance the utilization, and increase productivity of ruminants. Stockdale (2008) reported that over the last two decades, the increasing use of supplementary feeds, particularly cereal grain-based concentrates and by-products has contributed to increased production per cow and per farm in the Australian dairy industry.

Fat supplementation is a common practice for increasing energy density in diets fed to high-producing dairy cows without sacrificing fibre content (Kargar *et al*., 2010). Fat sources have played important roles in increasing energy density of diets and offer alternatives to feeding excessive amount of cereals, and thus prevent problems of ruminal acidosis, off-feed, lameness and low milk yield (Groehn *et al*., 1992 cited by Otaru *et al*. 2011). Supplementation of natural protein to ruminants consuming low-quality forage (<6% CP) improved forage intake, nutrient digestibility, animal performance and reproductive efficiency compared with non-supplemented controls, (Wiley *et al*., 1991; Bandyk *et al*., 2001; Bohnert *et al*., 2002 cited by McGuire *et al*., 2013).

Providing supplement to grazing animals is another way of compensating for the absence of good-quality forage (Van Soest, 1994); it can improve performance and carcass quality, but its high cost can limit its usage. Mamani-Linares and Gallo (2013) fed wheat bran/sorghum grain concentrate supplement overnight at rate of

0.30 kg/animal/day to young llamas grazing native pasture and observed greater live weight, greater carcass weight, greater fat deposits and improved carcass characteristics, and concluded that supplementation with concentrate was a good alternative in the production of llama meat, especially in the dry season where there is poor pasture availability. Several studies have shown that concentrate ration supplementation during prepartum period had impact on growth and improved goats productivity (Totanji and Lubbadeh, 2000; Madibela and Segwagwe, 2008). Bushara *et al.* (2010) fed 350 g/head/day of concentrate supplement to grazing Taggar goats to investigate effect of type of ration on productive and reproductive traits. The authors observed higher birth weight, higher weaning weight, lower milk fat, higher milk total solid, shorter kidding intervals and reduced incidence of abortions for the supplemented groups.

2.4.1 Concentrate Supplements (Energy, protein, vitamins and minerals)

The use of conventional feedstuffs such as maize, soybean cake, fish meal and others as supplement to low quality feed may not be cost effective in the present day Nigeria to intensify ruminant animals production, owing to their high cost, their irregular supply (Akintunmi, 2004) and the competition over them with both humans and monogastric animals (Adama, 2008; Ajayi *et al.*, 2008; Ukpabi and Abdu, 2009). Effective and economical sources of nitrogen (N) are needed as supplements for better use of crop residues in dairy diets (Sarwar *et al.*, 2002). Due to its lower cost per unit of N compared with most sources of natural protein, urea (non-protein N; NPN) is a popular source of supplemental N (McGuire *et al.*, 2013).

Supplements serve essentially to promote efficient microbial growth in the rumen, and/or increase nutrient supply for digestion in the small intestines. Protein supplement could be from non protein nitrogenous sources such as urea, and natural protein e.g. cottonseed cake, or multi-nutrient mixtures involving molasses and mineral sources made into liquid mixtures or solidified into blocks and served as multi-nutrient block licks (MNBL) or leguminous forages that have a low level of tannins (1-3%), dried or heat treated e.g. Acacia spp., *Gliricidia maculata* and *Leucaena leucocephela* (Devendra, 1996). To ensure better use of forage-based diets, the recommended supplements have to be energy-and protein-based supplements (Hersom, 2008). When conditions in beef cattle production demand increased energy intake, grain supplementation is often practiced (Carey *et al*., 1993). Corn supplementation at levels as low as 800 g/d in mature cattle has decreased *in vivo* cellulose digestibility and forage intake (Lusby and Wagner, 1986). However, increased concentrate intake increases the production of short-chain fatty acids and lowers rumen pH, possibly resulting in ruminal acidosis (e.g. Plaizier *et al*., 2008). This can even generate tympany (Lowman and Lewis, 1991), and increase the incidence of laminitis and liver abscesses (Nocek, 1997 cited by Manninen *et al*., 2010).

Readily digestible fibre sources such as soybean hull and immature forages fed as energy supplements to ruminants have increased forage intakes (Ørskov, 1991) and increased digestibility. For instance, brown midrib corn silage and sorghum silage have been shown to have less lignin and greater fiber digestibility than parent stock and have produced more milk when fed to cows (Oba and Allen, 1999; Aydin *et al*., 1999). Supplementation of energy may alter energy requirements of grazing ruminants by altering grazing behavior or by influencing efficiency of nutrient use

(Caton and Dhuyvetter, 1996). Pordomingo *et al*. (1991) reported that cattle supplemented with corn while grazing summer pasture had reduced forage intakes.

The commonest protein supplement used for ruminant feed in northern Nigeria is cottonseed cake (CSC). Cottonseed cake is obtained from cotton after the removal of the lint, followed by oil extraction from the seed. It has a protein content of 38-44% (Milo, 2010) depending on the efficiency of oil extraction but deficient in lysine, methionine, leucine and isoleucine (Ramesh, 2000 cited by Aruwayo and Maigandi, 2013). In forage-fed ruminants, supplementation of energy or N sources can improve rumen fermentation since carbohydrate and N degradation rates in forages are normally imbalanced (Van Soest, 1994). Nutrient supplementation may enhance rumen microbial population and VFA production (Mould *et al*., 1983).) Sawyer *et al*. (2012) cited by Mulliniks *et al*. (2013) reported that the use of small quantities of high supplemental ruminally undegradable protein (RUP) ingredients combined with salt and minerals sustained ruminal function of animals on low quality warm season forage diets. Mulliniks *et al*. (2012) reported lower calf morbidity in the feedlot by feeding dams small quantities of a high RUP supplement during late gestation. Thus, protein supplementation in a small quantity of high RUP may have the potential to decrease production costs while optimizing cow and calf performance (Mulliniks *et al*. 2013). The authors indicated that calves born from dams receiving a self-fed high RUP supplement, consumed at relatively low quantities, were treated less for sickness had decreased death loss, and had increased feedlot net profit.

Robinson (1994) reported that many dairy producers supplement a basal totally mixed ration (TMR) with mixed concentrates or grains to meet the nutritional requirements of higher producing dairy cows because of difficulties in formulating a single mixture for all lactating cows within a herd, with various levels of milk production at various stages of lactation. Adegun *et al*. (2011) have shown that provision of Moringa-based multinutrient blocks in small ruminants' diet can enhance better performance and pose no health challenges to the animals.

2.4.2 Supplementary Feeds and their Combinations for Efficient Use of Roughages

The inclusion of supplemental feeds creates a complexity in the feeding scenario that may result in an improved or detrimental animal response (Moore *et al*., 1999). Supplemental feeds often times have physical structure, solubility, degradation, and chemical characteristics that are different from the base forage utilized. The respective differences may be advantageous to the manipulation of nutrient synchrony. In contrast, the properties of the supplement may exacerbate an asynchronous dietary nutrient supply. In that regard, negative associative effects would be detrimental to the process of dietary nutrient synchrony (Hersom, 2008).

Rumen microorganisms use carbohydrate as the main energy sources although protein also can be used. When adequate energy sources are supplied in the rumen, ammonia N can be converted to microbial protein. If the rate of protein degradation exceeds that of carbohydrate fermentation, large quantities of N are converted to ammonia, and likewise, when the rate of carbohydrate fermentation exceeds that of protein degradation, inefficient microbial protein synthesis may occur (Bach *et al*., 2005). Therefore, synchrony between the supply of energy and N to the rumen microorganisms should improve the efficiency of the rumen microbes in capturing N and use of energy for microbial growth (Yang *et al*., 2010). Since anaerobic fermentative digestion in the rumen provides microbial cells which supply the protein to the animal, the efficiency of microbial growth therefore influences the protein: energy (P/E) ratio in the rumen. Poor microbial growth due to inadequate dietary N for example will result in a low P/E ratio and, conversely, adequate supplementation and good rumen function enables a good P/E in the nutrients available to the animal (Leng, 1982).

According to Hersom (2008) the most frequent supplement strategies include controlling the timing of feed and nutrient delivery, the form in which the nutrients are supplied and supplement types, and finally, attention to the balance of energy to protein in the diet. An important observation is that each particular type of supplement (i.e., energy or protein) also generally supplies other ancillary nutrients. The complement of energy and protein in supplements may increase the likelihood of dietary nutrient synchrony in forage fed cattle (Hersom, 2008), but more important is the synchronization of the rate of degradation of feed nitrogen and carbohydrate or organic matter components (Rusell and Hespell, 1981; Orskov, 1982).

The strategic supplementation with limiting nutrients become the best option for cattle management, especially when this supplementation is based on feeding nitrogenous compounds, which stimulates the cellulolytic activity in the rumen and increases the utilization of low-quality fibrous carbohydrates (Costa *et al*., 2008; Detmann *et al*., 2008 cited by Detmann *et al*., 2009). Also, Currier *et al*. (2004) studied the effects of urea or biuret supplementation on ruminants consuming low-quality forages and found that total DM, OM, and N intake; DM, OM and N digestibility; N balance; and digested N retained were greater for supplemented groups than for unsupplemented control group. However, decrease in voluntary intake associated with excess use of nitrogenous compounds supplements such as urea and ammonium sulfate were also observed by other authors when they fed cattle with low-quality forage supplemented with ammonium sulfate, urea and albumin (Lazzarini, 2007; Sampaio, 2007).

Mertens and Loften (1980) reported that supplementation of forages with starch decreased fiber utilization in vitro. Rapid fermentation characteristics of starch supplements often exceed the ability of ruminants to maintain a stable ruminal pH (Orskov and Fraser, 1975) and as pH decreases, cellulolytic bacterial function is often impaired and fiber digestion decreases. Sanson *et al*. (1990) demonstrated that increasing levels of cornstarch supplementation decreased forage intake in steers. These reductions have been attributed to either depressions in ruminal pH or a carbohydrate effect (Bargo *et al*., 2002). Declining ruminal pH associated with increasing dietary starch should affect the ruminal bacteria toward greater amylolytic and lower cellulolytic population. Resulting bacteria shifts are thought to reduce fibre digestion and negatively affect intake of grazed forage (Caton and Dhuyvetter, 1997). However, increased forage intake had been reported when sheep were fed low levels of corn supplement (7.8% of DM intake) (Henning *et al*., 1980; Matejovsky and Sanson, 1995).

Maximum fermentation rates are attained when all factors required by the ruminal microorganisms are available, namely- a source of energy (sugars, cellulose), nitrogen (N), sulphur (S) and minerals. When the rate of fermentation is restricted feed intake decreases; and nutrient availability to the animal is likewise limited (Norton, 1994). Sharma, *et al*. (2008) evaluated the feeding value of Oak (*Quercus* *incana*) leaves (OL) as a supplement to wheat straw (WS) in calves. The authors observed that supplementation of WS/OL ratio of 44:56 enhanced DMI, digestibility, efficiency of N utilization and body weight gain compared with a WS/OL ratio of 100:0. The increase in total DMI was reported to be associated with improved N and energy supply to cellulolytic bacteria (Chakeredza *et al.*, 2002), leading to increased degradation rate of poor quality roughage, and to a higher digesta passage rate (Goodchild and McMeniman, 1994). Manipulating rumen fermentation through strategic supplementation with concentrate and forages could improve rumen efficiency through maintaining optimum pH, optimizing volatile fatty acids (VFAs) and ammonia-nitrogen (NH_3-N) utilization for microbial protein synthesis and reduction of methane (CH_4) production thereby enhancing the productivity of ruminants in the tropics (Khampa and Wanapat, 2007).

One way of utilizing fodder trees is to use them as feed to small ruminants as part of, or along with, multi-nutrient blocks (MNBs) (Agbede and Aletor, 2004; Aye, 2007). According to Habib *et al*. (1991), MNBs create an effective ecosystem and increase intake and digestibility of low quality, high fibre grasses usually consumed by the small ruminants. Exogenous fibrolytic enzymes hold a lot of promise as mean of increasing forage utilization, milk production, average daily weight gain and improving the productive efficiency of ruminants. They are, however, limited by their hydrolysis in the rumen environment (Peters *et al.*, 2010). Fon and Nsahli, (2013) stated that as a result of banning the use of antibiotics in ruminant feeds to improve feed efficiency and promote growth, supplementing fibrous forages with probiotics that can survive in the rumen has become a substitute. They further stated that if these microbes can colonize and establish in the rumen, fibrolytic enzyme availability would be continuous. Milk production, average daily weight gain, dry matter intake, microbial population, fibre utilization and animal performance have shown marked increase when ruminant animals are supplemented with direct-fed microbial consortia (Aydin *et al*., 2009). However, Raeth-Knight *et al*. (2007) did not observe any significant change in the digestibility parameters of Holstein dairy cows when supplemented with direct-fed microbial consortia.

2.5 RUMEN ENVIRONMENT AND NUTRIENT SYNCHRONY

The rumen is an environment with a diverse population of microorganisms, consisting of bacteria (10^{10}-10^{11} cells/ml, of more than 50 genera), ciliate protozoa (10^4-10^6/ml, of 25 genera), anaerobic fungi (10^3-10^5 zoospores/ml, of five genera) and bacteriophages (10^8-10^9/ml) (Kamra, 2005). The rumen microorganisms ferment dietary carbohydrates and protein to obtain energy and N for maintenance and growth. Through this process, the two major nutrients or products (i.e. VFA and microbial protein) for the host animal are produced (Yang *et al*., 2010). Microbial protein synthesis (MPS) is important in ruminants because microbial protein synthesized in the rumen provides from 50% to nearly all amino acids required by ruminants, depending on the rumen undegraded protein (RUP) concentration of the diet (NRC, 2000). Non-structural carbohydrate (NSC)-fermenting microorganisms usually represent a predominant population of rumen microbial flora in high-producing ruminant animals, such as lactating dairy cows and feedlot beef cattle. The nitrogen requirement of NSC-fermenting microbes can be met by either ammonia or peptides and amino acids (Russell *et al*., 1992).

Microbial processes in the rumen confer the ability on ruminants to convert fibrous feeds and low quality protein, even non-protein nitrogen, into valuable nutrients for the ruminant animal (Dewhurst *et al*., 2000 cited by Chandrasekharaiah *et al*., 2012). Microbial proteins synthesized within the rumen provide a major source of amino acids to ruminant animals. The ruminal microbial ecosystem can be divided into two groups, microbes that ferment structural carbohydrate and those that ferment non-structural carbohydrate (NSC, Russell *et al*., 1992).

According to Kung (2011), the optimum pH of the rumen for efficient and effective fermentation or degradation of feeds (especially fibre) ranges from 6.2 to 6.8. At pH below 6.0 - 6.2, fibrolytic bacteria in the rumen become less active and fiber digestion is decreased. Further decrease in pH to between 5.8-5.9 causes mildly acidic rumen environment and cessation of fiber digestion. Excessive feeding of concentrate, especially grains has been implicated as the cause of acidosis in ruminants when rumen pH falls below 5.0 – 5.2 (Allen, 1997; Carro *et al*., 2000). Kanjanapruthipong and Leng (1998) reported that ruminal fluid ammonia is the major source of nitrogen for microbial synthesis and growth and that critical levels of has been from 50 to 250 mg of ammonia-nitrogen/ litre of rumen liquor.

The term "synchrony" derived from Greek for "together" and "time", means simultaneous occurrences in general (Hall and Huntington, 2008). In ruminant nutrition, "nutrient synchrony" means parallel occurrence of both rumen degradable protein (RDP; non protein N and rumen degradable true protein) and energy (ruminally fermentable carbohydrates) for the ruminant animal to consume or be present in the diet and rumen, so that an increase or optimization of microbial efficiency would occur (Hersom, 2008; Yang *et al*., 2010). The synchronic ingestion of protein and energy is important for the ruminant micro flora (Schilcher, *et al*., 2013).

Feeding cows excessive amounts of physically effective fibre decreases feed intake and lowers feed efficiency due to reduced microbial protein synthesis (Yang and Beauchemin, 2006). The synchronization of the ruminal degradation rate of carbohydrates and protein has been shown to increase ruminal microbial protein synthesis (MPS), improve efficiency of N usage and animal performance, and decrease urinary N excretion (Cole and Todd, 2008) because of simultaneous capturing of N and use of ATP (adenosine triphosphate) by microbes for their growth (Richardson *et al*., 2003; Elseed, 2005; Chumpawadee *et al*., 2006; Baah *et al*., 2011)). Some experimental evidences indicated that low nitrogen content of low-quality forages could limit the availability of microbial fibrolytic enzymes in the rumen. Thus, the main effect of the supplementation with nitrogenous compounds would be the higher supply of nitrogenous precursors for the synthesis of microbial enzymes (Costa *et al*., 2008; Detmann *et al*., 2008; Souza, 2007 cited by Detmann *et al*., 2009).

According to Hersom (2008), parameters such as ruminal pH, total VFA and individual acid concentrations, and ammonia concentration, microbial nitrogen yield, and body weight (BW) gain, milk production, or carcass weight accreted are useful indicators of synchrony of release of nitrogen and energy in the rumen during dietary degradation. For example, Chumpawadee *et al*. (2006) fed diets containing 3 levels of synchrony index (0.39. 0.56 and 0.74) to Brahman cattle at the rate of 2.5% body weight by separate concentrate and roughage. The authors observed linear increase in average daily gain, dry matter, organic matter and neutral detergent fibre digestibility, and ruminal total volatile acids concentration at 6 h post feeding. They concluded that synchronized rate of dietary energy and nitrogen degradation improved ruminal fermentation and digestibility which led to higher growth rate in Brahman cattle fed with straw-based diets.

A rapid release of nitrogen not matched to the release of organic matter from the carbohydrate source could lead to a high absorption of ammonia from the rumen. In that regard, ammonia not captured in the rumen is absorbed and converted into urea in the liver (Baah *et al*., 2011). According to Yang *et al*. (2010), there are several ways to supply energy and N to the rumen synchronously. These include: i) changing the concentrate: forage ratio; ii) supplementation of energy or protein sources; iii) using index values and; iv) change in feeding frequency or pattern. Newbold and Rust (1992) suggested that even if the total amount of rumen degradable protein supplied each day meet the requirement of rumen microbes, difference between feeds in rate of degradation of protein or energy substrate may cause short-term imbalances between nitrogen and energy supply to rumen microorganisms. Sinclair *et al*. (1993) and Khorasani *et al*. (1994) recommended synchronizing the rate of organic matter and nitrogen degradation for optimal microbial protein synthesis in the rumen.

Studies in sheep (Trevaskis *et al*., 2001; Richardson *et al*., 2003) and dairy cows (Kim *et al*., 1999) indicated an improvement in microbial efficiency and yield when provided with synchronized nutrients. Richardson *et al.* (2003) examined the effect of calculated dietary synchrony index on growing lamb performance and observed no difference in the ADG (0.187 kg/d) and efficiency of gain (0.178 kg/kg). The authors, however, recorded lower retained energy (0.079 MJ retained/MJ of intake) for lambs fed asynchronous diet compared with lambs fed the intermediate or synchronous diet (0.095 MJ retained/ MJ of intake). Also, Kim *et al*. (1999) fed carbohydrate supplement (sucrose) to dairy cows in a continuous, synchronous or asynchronous pattern and observed no effect on ruminal pH or total VFA production compared with basal diet of grass silage.

2.6 FEEDING REGIMES IN SMALL RUMINANT PRODUCTION

In ruminant production, feeding regime is used to describe a regulated system/pattern of what meals are been offered, how frequently they are offered, what sequence is followed, and during which particular period they are offered. In Nigeria, small ruminants' management system may be extensive, intensive or semi-intensive. According to Oludimu (1992) and Lakpini (2002), under the extensive management system, goats and sheep graze on large expanse of land or scavenge all day to feed themselves. At best, they are offered feed supplements such as kitchen refuse, cassava/yam/ banana peelings, bean husks and maize chaff. The animals raised under this system are very destructive to crops, and are prone to diseases, risk of theft and parasites infestation which result in low productivity (Weaver, 2005). In intensive type of management system, animals are completely confined and provided feed using the cut-and-carry (zero-grazing) method in which leguminous trees planted in alley farms or intensive feed gardens provide a high-protein diet to small ruminants. Intensive system of management ensures higher growth rate, carcass yield, milk yield, litter sizes and survival rates. But, it is not advised for the rural poor due to the level of input on feeding and health care (Gefu, 2002; Lakpini, 2002). Huijsman (1987) remarked that there is a substantial increase in reproductive performance of dwarf goats when the animals are kept under intensive management. The author recorded productivity of 10.9 kg liveweight/doe/year under extensive management compared to 24.2 kg liveweight/doe/year in the intensive management system.

Semi-intensive system of management involves allowing the animals to graze for 6 to 8 hours and supplementing them with concentrates after returning to the pens in the evening. Growth and survival rates of animals are high under this system, though it can only be practiced where grazing land is available or during the dry season when crops have been harvested (Lakpini, 2002; Ugwu, 2007). For instance, Osinowo *et al*. (1992) reported that sheep managed under semi-intensive system are allowed to graze on improved and sown pasture for 6-8 h daily, with 0.3-0.5 kg/day of 15-20% CP concentrate supplement throughout the year, depending on the animal's physiological status. In addition, changing the frequency of concentrate supplementation such as feeding the supplement in alternate days or every third day (e.g. Tellier *et al*., 2004) is another feeding regime being employed in ruminant animals production.

Supplementation in most areas where domestic ruminants graze is a major factor to consider when making management decisions. Providing nutrients to offset deficiencies or to meet production demands is more often practiced during the dry season in the tropics and in the periods of summer dormancy or in the fall and winter months in temperate regions (Caton and Dhuyvetter, 1997; Detmann *et al*., 2009). In situations where optimum sward conditions cannot be maintained, and the nutrient intake of animals falls below the required level, one option available is to provide supplementary feeding. Supplements are usually offered in the morning, when the animals have just completed the first grazing season (Carro *et al*., 1994). However, irrespective of the management system, it is important to increase the proportion of forage in the diet to reduce or minimize cost (Bouwman *et al*., 2005) bearing in mind the production objective. Feeding regime, like the number of meals and the sequence of feeding roughage and concentrates during feeding is important to prevent sub-acute ruminal acidosis (Nordlund *et al*., 1995). The levels of rumen metabolites (VFAs, NH_3-N) and pH are closely related with feeding regime (Steger *et al*., 1970).

2.7 RESPONSE OF RUMINANTS TO SEQUENCE AND FEEDING INTERVAL OF SUPPLEMENT AND ROUGHAGES

Schilcher *et al*. (2013) investigated the rumen health of different wild ruminant species in relation to feeding managements. In the morning, the test animals were offered with a mixture of concentrates, vegetables and fruits, and at the same time hay. They observed severe lesions on the rumen mucosa of the animals which are fundamental characteristics of subacute ruminal acidosis (Krause and Oetzel 2006). This is because of initial low hay intake as the animals usually eat the concentrate mixture in preference before hay. The authors, therefore, suggested that roughage be offered in the morning before the concentrate meal. Earlier, Morita and Nishino (1991) offered diets to steers separately by feeding hay before concentrate and observed greater DMI in steers fed hay before concentrate compared to their counterparts fed concentrate before hay. Similar results were obtained when this sequence of feeding (concentrate supplement fed 40 min before or after feeding hay) was compared with feeding mixed diet of hay and concentrate (Morita and Nishino, 1993). However, Nocek *et al*. (1986) observed that the amount of DM intake increased when the mixed ration was offered. On the other hand, some reports pointed out that offering the mixed ration had no effect on DM intake (Holter *et al*., 1977). Voight *et al.* (1978) cited by Morita and Nishino (1993) reported that cellulose digestibility in the fore stomach increased when chopped ryegrass was fed before feeding barley or corn.

Zeyner *et al.* (2004) studied the effects of hay intake and feeding sequence on variables in faeces and faecal water of horses. They found that the horses fed forage 30 min before the concentrate instead of the opposite had higher faecal pH (6.6) and higher faecal buffering capacity (108 mmol/l), compared to faecal pH (6.4) and buffering capacity (84 mmol/l) of horses fed concentrate 30 min before forage. The concentration of acetic acid was higher, the propionic acid lower, and the ratio acetic/propionic acid was higher in the faecal water of horses fed forage before concentrate. The authors concluded that feeding forage before concentrate gives a higher buffering capacity in the hindgut which might protect against acidification of the colon content upon decrease in pH sequel to ingestion of concentrate.

Nocek (1992) showed that manipulating feeding sequences alone can impact performance of primiparous cows. Changing feeding frequency or pattern was employed in some nutrient synchrony studies to assess the effects of feedstuffs on simultaneous availability of energy and N. Because these studies use the same ingredients and alter feeding pattern only, any change in metabolite patterns in the rumen may be due to variation in degradation rates of nutrients in the rumen (Yang *et al.*, 2010). Kaswari *et al.* (2007) studied the relationship between synchronization index and microbial protein synthesis in the rumen by using different feeding frequency and pattern, and observed that when energy sources (maize grain, grass silage, grass hay, wheat grain or maize silage) were offered first before protein sources (soyabean meal or peas+ urea), microbial activity was improved although synchrony index (i.e. measure of synchrony between N and energy supply throughout the day which is derived from laboratory chemical analysis and degradation kinetics using nylon bag technique) was low.

Robinson (1989) implicated rapid fermentation of starch in an unbuffered rumen as the cause of rapid decline in rumen pH when concentrate feeding preceded that of forage. In a related study, Beauchemin and Buchanan-Smith (1990) showed that feeding supplemental grains prior to forage can reduce overall forage intake. This could be as a result of rapid decline in pH value of the rumen. Voight *et al*. (1978) cited by Robinson (1994) recommend feeding of forages before concentrates in order to optimize rumen function. Robinson *et al*. (1992) showed that changing the feeding strategy of protein supplements can modify rumen outflow patterns leading to modified diurnal patterns in nutrient flow to the intestine. However, Robinson (1994) fed rolled barley or a mixture of rolled corn and soyabean meal 1 h prior to, or after feeding mixed ration to primiparous dairy cows. He observed that the influence of modifying the sequence of feeding grain and forage on productivity of dairy cows was not consistent. The author stated that the numerical differences in virtually all production parameters favoured feeding grain subsequent to the forage-based mixed ration, regardless of rumen fermentability of the supplemental grain. He further observed that the magnitude of the numerical differences were too small to be of productive benefit and attributed it to relatively small amount of grain fed(less than 20% of total DMI) separately from the mixed ration and concluded that the differences between treatments might have been larger if the amount of grain fed had been greater.

It was concluded (Robinson, 1994) that the productivity of late lactation primiparous cow was not modified by changing the sequence of feeding supplemental grain relative to a forage- based mixed ration, and in addition, the effect of the feeding sequence on animal performance was not influenced by the rumen fermentability of the grain. But, Beauchemin (1992) recommended to dairy producers that forages should be fed before starch-rich concentrates, particularly in the morning, in order to increase rumen buffering capacity. And alternately, less rapidly fermentable starch sources, such as corn, should be substituted to reduce the rate of production of volatile fatty acids and lactic acids. Both of these practices have been reported (Robinson, 1989; Beauchemin, 1992) to result in higher intake of forage and increased overall animal productivity. Furthermore, Carro *et al*. (1994) studied the effect of time of supplementary feeding on performance of sheep. The authors offered cereal-based concentrate supplement 1 h after feeding hay in the morning and 30 min before feeding hay in the afternoon, at the rate of 700 g/sheep/d, and observed a higher total OM intake when concentrates were given after rather than before a period of ingestion of hay. This suggests that feeding supplement after rather than before a major grazing bout may be an effective means of minimizing reduction in forage intake as a consequence of feeding concentrate.

CHAPTER THREE

MATERIALS AND METHODS

3.1 LOCATION OF THE STUDY

The study which lasted for 90 days, after two weeks adjustment period, was conducted at the Experimental Unit of the Small Ruminants Research Programme of National Animal Production Research Institute (NAPRI), Ahmadu Bello University, Shika, Zaria, Nigeria. Shika is located within the Northern Guinea Savannah Zone on latitude 11^0 11'N and longitude $7^0$34'E, and is 640 m above the sea level (Macmillan Nigeria, 2006; Ovimaps, 2012). Annual rainfall is 1100-1200 mm while mean temperature is about 24.4 ˚C (14.5-39.3 ˚C) with the lowest temperature occurring during the early dry season (October-December) while the higher temperatures are experienced during the late dry season (January-March). Drought or dry spells occur occasionally. Key forage species in this zone include grasses such as *Digitaria smutsii*, *Andropogon gayanus*, *Hyparrhenia spp*, *Brachiaria spp*, *Setaria sphacelata*, *Sporobalus pyramidalis*, *Echinochloa spp*, *Pennisetum pedicillatum* and *Pennisetum polystachyon*, with potential yield of 5,000 – 15,000 kg DM/ha. Bunaji cattle with Yankasa sheep and Red Sokoto goats are the predominant breeds in this region (Osinowo *et al*., 1991; Kallah, 2004; Aregheore, 2009).

3.2 ANIMALS AND EXPERIMENTAL DESIGN

Twenty-eight Yankasa weaner rams of average live weight of 14.96 ± 1.10 kg (5-6 months old) were separated from the sheep flock of the Small Ruminant Research Programme, National Animal Production Research Institute and used in a randomized complete block design with a 2 x 2 factorial arrangement of treatments to evaluate the sequence and interval of feeding concentrate supplement (CS) and roughage on intake and performance. The animals were blocked according to weight and randomly allocated to four treatments to give a total of seven animals per treatment group. The animals in treatment 1 were offered concentrate supplement 1 h before feeding grass hay, while those in treatment 2 were offered concentrate supplement 2 h before feeding grass hay. The animals in treatment 3 were given grass hay 1 h prior to feeding concentrate supplement, and those in treatment 4 were given grass hay 2 h prior to feeding concentrate supplement.

3.3 EXPERIMENTAL DIETS AND MANAGEMENT OF ANIMALS

The experimental diets consisted of Wooly finger grass (*Digitaria smutsii*, Stent) hay, and the concentrate supplement mixture compounded to contain 15% CP. The concentrate mixture was composed of maize offal, cottonseed cake, bone meal and common salt as shown in Table 1. Before the commencement of the trial, the lambs were dipped in acaricide solution to control ecto-parasites. They were dewormed with a broad spectrum antihelminth (Zambezole®) to control internal parasites. Thereafter, the animals were weighed, and subsequently blocked for weight and randomly assigned to each of the treatment groups. The animals were housed in individual feeding pens and offered feed. The diets were offered to the animals daily at about 0900 h after the previous day's refusal had been collected and weighed. The hay and CS diets were separately offered at the rate of 2.4 % and 1.6 % of body weight, respectively, to correspond to a ratio of 40% CS: 60% hay. During each feeding time, the animals in treatments 1 & 2 were offered CS at 1 & 2 h, respectively, before feeding the grass hay, while the animals in treatments 3 & 4 were given the grass hay at 1 & 2 h, respectively, before offering the CS. Water was offered *ad libitum* and changed every morning. After an initial adjustment period of 14 d, records were taken of the quantity of feeds offered and refused in order to determine the voluntary feed intake. Fortnightly, weights of the animals were taken and the quantity of feeds offered adjusted accordingly. Initial and final weights of the animals were taken at the beginning and end of the experiment, respectively.

Table 3.1. Ingredient composition of concentrate supplement (%)

Ingredients	Composition (%)
Maize offal	65.60
Cottonseed cake	32.40
Bone meal	1.50
Common salt	0.50
Total	100.00

3.4 MEASUREMENT OF BLOOD AND RUMEN METABOLITES

Five animals from each treatment were bled every four weeks. Blood collection was done before the first feeding and 4 h after the second feeding. During each bleeding time, 5 ml of blood was collected from each animal by jugular veni-puncture into test-tube and centrifuged immediately at 3000 rpm for 10 min using MSE minor centrifuge. The serum which had separated from cells was carefully decanted into serum vials. Serum samples were stored in deep freezer (-4^0C) before analysis for glucose, urea nitrogen, protein and creatinine within 10 d of collection. During the last week of the feeding trial, rumen fluid was collected from the animals before the first feeding and 3 h after the second feeding by aspiration method using stomach tube. The rumen fluid was collected into plastic containers, and the pH of the fluid was immediately taken. The fluid was strained through muslin clothe before 25 ml aliquot of the filtrate was taken and mixed with an equal volume of 1 N H_2SO_4 saturated with $MgSO_4$ to acidify and de-proteinize as well as reduce bacteria activity, respectively. This mixture was allowed to stand for 10 minutes and then centrifuged at 6000 rpm for 5 min. Thirty milliliters of the supernatant was then decanted into plastic bottle and kept in deep freezer (-4^0C) until analyzed for total volatile fatty acids (VFAs) and rumen ammonia-nitrogen (NH_3-N).

3.5 METABOLISM TRIAL

3.5.1 Animals, Design and Experimental Procedure

Twenty (20) animals selected from the four treatment groups used for the feeding trial were housed in metabolism crates, for nutrient digestibility and nitrogen balance studies. There were four treatment groups of five animals each. Animals in each treatment groups were offered feed as in the feeding trial. Animals were allowed seven (7) days adjustment to the new environment since the diet remained same, before measurements of total urine and faecal outputs were taken for seven consecutive days. For each animal, total urine output was collected into a plastic container containing 50 ml of 0.1N H_2SO_4 to prevent ammonia loss from the urine. Ten per cent of each day's collection was taken for each animal and later bulked for the seven (7) days. The bulk was again sub-sampled and stored in a deep freezer until it was analyzed for nitrogen. Total faecal output from each animal was also collected and weighed fresh. Ten percent of each day's collection was also taken and bulked, oven-dried for 48 h at 70^0C, milled and stored in plastic containers for proximate analysis.

3.6 CHEMICAL ANALYSIS

The nitrogen in the feeds, faeces and urine was determined according to Kjeldahl procedure (AOAC, 2000). The feed and faecal samples were analyzed for dry matter (DM), crude fibre (CF), ether extract (EE), crude protein (CP) and ash according to standard methods (AOAC, 2000). Analysis of neutral detergent fibre (NDF) and acid detergent fibre (ADF) was done following the procedures of Van Soest *et al.* (1991). Rumen ammonia-nitrogen (NH_3-N) was determined by steam distillation method (Markham, 1942 cited by Otaru *et al.*, 2011). Volatile fatty acids (VFAs) were also determined by steam distillation according to procedure described by AOAC (2000). Blood metabolites were analyzed using Roche Hitachi 902 Auto-analyzer according to the technique of Leonard (1957).

3.7 CALCULATIONS AND STATISTICAL ANALYSES

Non-structural carbohydrate (NSC) concentrations of the diets were estimated using the equation: OM – (CP% + NDF% + ether extract %) (Ariel *et al.*, 2005 cited by Otaru *et al.*, 2013). The energy contents of the diets were calculated using the method of Alderman (1985). ME (MJ/kg DM) = $11.78+0.00654\ CP + (0.000665\ EE)^2$ – CF

(0.00414 EE)-0.0118Ash. Data on daily intake of nutrients, DM, water, weight gain and blood metabolites, whose values were correlated because of repeated measures, were subjected to analysis of variance (ANOVA) for repeated measure analysis using PROC MIXED procedure of SAS (SAS, 2002). The variables analyzed were subjected to four covariance structures: Compound symmetry (CS), unstructured (UN), first order autoregressive [AR (1)] and autoregressive heterogeneous [ARH (1)]. The covariance that yielded the smallest Akaike's Information Criterion (AIC) was used. Data on digestibility coefficients of nutrients, urine and faecal outputs, nitrogen intake and retention, rumen metabolites and pH were analyzed by ANOVA using the General Linear Model (GLM) procedures of the Statistical Analysis systems (SAS, 2002). The treatments means were separated using Tukey's Honestly Significant Difference (HSD).

Model equation:

$Y_{ijk} = \mu + B_i + S_j + H_k + (SH)_{jk} + E_{ijk}$

Where:

Y_{ijk} = individual observation

μ = overall mean

B_i = effect of the blocks

S_j = effect of ith sequence (before, after)

H_k = effect of jth hour (one hour, two hours)

$(SH)_{jk}$ = Effect of interaction of ith sequence with jth hour

E_{ijk} = Random error

CHAPTER FOUR

RESULTS

4.1 FEEDING TRIAL

4.1.1 Composition of Diet

The ingredients composition of the concentrate diet is presented in Table 3.1. Table 4.1 shows the chemical composition and metabolisable energy (ME) content of the Wooly finger grass (*Digitaria smutsii*, Stent) hay and the concentrate supplement used in the feeding and metabolism trials of this study.

4.1.2 Voluntary Feed Intake

The mean daily intake of grass hay (Table 4.2) ranged from 291.74 g/d to 325.63 g/d, with the rams fed grass hay first and supplemented with concentrate mixture 2 h later (Treatment 4) having the least hay intake which was significantly ($P < 0.05$) different from the intake by rams fed concentrate first and offered grass hay 2 h later (Treatment 2) or those fed grass hay before being supplemented with concentrate mixture one hour later (Treatment 3). Neither sequence nor interval of feeding concentrate supplement (CS) and grass hay had significant ($P > 0.05$) effect on the intake of grass hay. However, their interactions had a significant ($P < 0.05$) effect on grass hay intake. For instance, an increase of 4.25 % in intake of grass hay was observed when CS was offered 2 h before feeding grass hay, but when grass hay was fed 2 h before CS was given, grass hay intake decreased by 9.04 %. With respect to concentrate intake (Table 4.2), the least intake (209.23 g/d) was observed in treatment 1 (rams fed concentrate 1 hour before being fed grass hay) which was only significantly ($P < 0.05$) different from treatment 2 (rams fed concentrate 2 hours before being fed grass hay) with the greatest value of 244.18 g/d.

Table 4.1. Chemical composition and energy content of the experimental feeds

Parameters	Concentrate supplement	Hay (*D. smutsii*)
Dry matter (%)	92.00	93.50
Crude protein (%)	15.00	7.50
Neutral detergent fibre (%)	44.00	68.00
Acid detergent fibre (%)	13.00	45.50
Ash (%)	11.00	7.00
Metabolisable energy (MJ/kg DM)	11.09	10.78

Table 4.2. Feed intake, liveweight change and feed efficiency of Yankasa weaner rams as influenced by sequence and feeding interval of concentrate supplement and roughage feeds

	Feeding sequence					Level of Significance		
	Concentrate before grass		Grass before concentrate					
Parameters	1hr (T1)	2hrs (T2)	1hr (T3)	2hrs (T4)	SEM	FS	FI	Interaction
Feed intake(g/d)								
Hay	311.78	325.63	320.72	291.74	28.33	NS	NS	*
Concentrate	209.23	244.18	239.15	232.83	25.46	NS	*	**
Total DMI	521.01	569.82	559.86	524.57	52.52	NS	NS	*
DMI as %BW	3.38	3.86	3.62	3.64	0.13	NS	**	**
DMI /kg$W^{0.75}$	66.83	75.33	71.08	70.86	3.24	NS	**	**
Live weight(kg)								
Initial	15.23	14.81	15.44	14.35	1.64	NS	NS	NS
Final	16.38	17.64	17.79	17.48	1.65	NS	NS	NS
Weight change	1.14	2.83	2.35	2.90	0.32	NS	**	*
ADWG(g/d)	10.26	28.28	23.55	31.13	7.93	NS	*	NS
FE (g gain/kg of feed)	18.29	55.56	35.54	57.39	13.17	NS	*	*

ADWG=average daily weight gain, BW=body weight, FE=feed efficiency, NS=not significant (P > 0.05), SEM=standard error of the means,
*= significant at (P < 0.05) **= significant at (P < 0.01)
FS = feeding sequence, FI = feeding interval

Although changing the sequence of feeding CS and grass hay did not affect concentrate intake significantly ($P > 0.05$), the interval of feeding CS and grass hay had a significant ($P < 0.05$) effect on intake of concentrate. For example, concentrate consumed by rams fed CS and grass hay at 2 h interval was 6.00 % higher than those offered CS and grass hay at 1 h interval. In addition, the effect of interaction between the sequence and interval of feeding CS and grass hay was significant ($P < 0.01$) on concentrate intake. For instance, an increase of 14.27 % in concentrate intake was recorded when CS was given 2 h before feeding grass hay, compared to an increase of 2.64 % when grass hay was fed 2 h before CS was offered.

Likewise, the mean values for total DMI in absolute terms (Table 4.2) ranged from 521.01 g/d to 569.82 g/d, and ranged from 66.83 g/kgW$^{0.75}$ to 75.33 g/kgW$^{0.75}$ based on metabolic liveweight, with the greatest values recorded for animals in treatment 2 (CS offered 2 h before feeding grass hay) and the least values for treatment 1 animals (CS offered 1 h before feeding grass hay). While the sequence and interval of feeding CS and grass hay had no significant ($P > 0.05$) effect on total DMI in absolute terms, their interactions had a significant ($P < 0.05$) influence. For example, at 2 h feeding interval, the weaner rams offered CS prior to feeding grass hay recorded greater (8.57 %, $P < 0.05$) DM intake in absolute terms, while the rams fed the grass hay prior to feeding CS had lower intake (6.30 %, $P > 0.05$) of DM in absolute terms. However, based on MW, there was no significant ($P > 0.05$) effect of changing the sequence of feeding CS and grass hay on total DMI, but the interval, and the interactions between the sequence and interval of feeding CS and grass hay significantly ($P < 0.01$) affected total DMI. For instance, rams fed grass hay and CS at 2 h interval had greater (5.66 %, $P < 0.01$) total DMI on MW than the ones given CS and grass hay at 1 h interval. Likewise, for interaction effect, at 2 h interval, there was an increase of 11.28 % ($P < 0.01$) in DMI based on MW when CS was fed before grass hay, and a decrease of 0.31 % ($P > 0.05$) when grass hay was offered before CS.

The daily DMI of animals in each treatment over time is shown in Fig. 4.1. There was increase in dry matter intake over time except in the 6th week where there was a decrease in intake. In the 12th week all but treatment 4 (grass hay fed 2 h prior to feeding CS) animals showed little decrease in intake. Animals in treatment 3, followed by those in treatment 2 (CS fed 2 h prior to feeding grass hay), most times exhibited higher intakes compared to other treatments.

4.1.3 Liveweight Changes

The effects of the sequence and time interval of feeding CS and grass hay on the animal mean daily live weight changes are shown in Table 4.2. In this study, all the animals had positive weight changes. Greatest (2.90 kg) and least (1.14 kg) mean total weight gains were observed in treatment 4 (fed grass hay 2 h before CS was given) and treatment 1 (rams fed concentrate 1 hour before being fed grass hay) animals, respectively. The total weight gain was significantly ($P < 0.01$) affected by the feeding interval. For example, weaner rams offered the second feed at 2 h interval gained more (39.16 %) weight than those given the second feed at 1 h interval. Also, there was a significant interaction in the total weight gain ($P < 0.05$) between the feeding sequence and feeding interval. At 2 h interval, the total weight gain increased by 59.72 % ($P < 0.05$) when CS was fed prior to feeding grass hay, and increased by 18.97 % ($P > 0.05$) when grass hay was given prior to feeding CS.

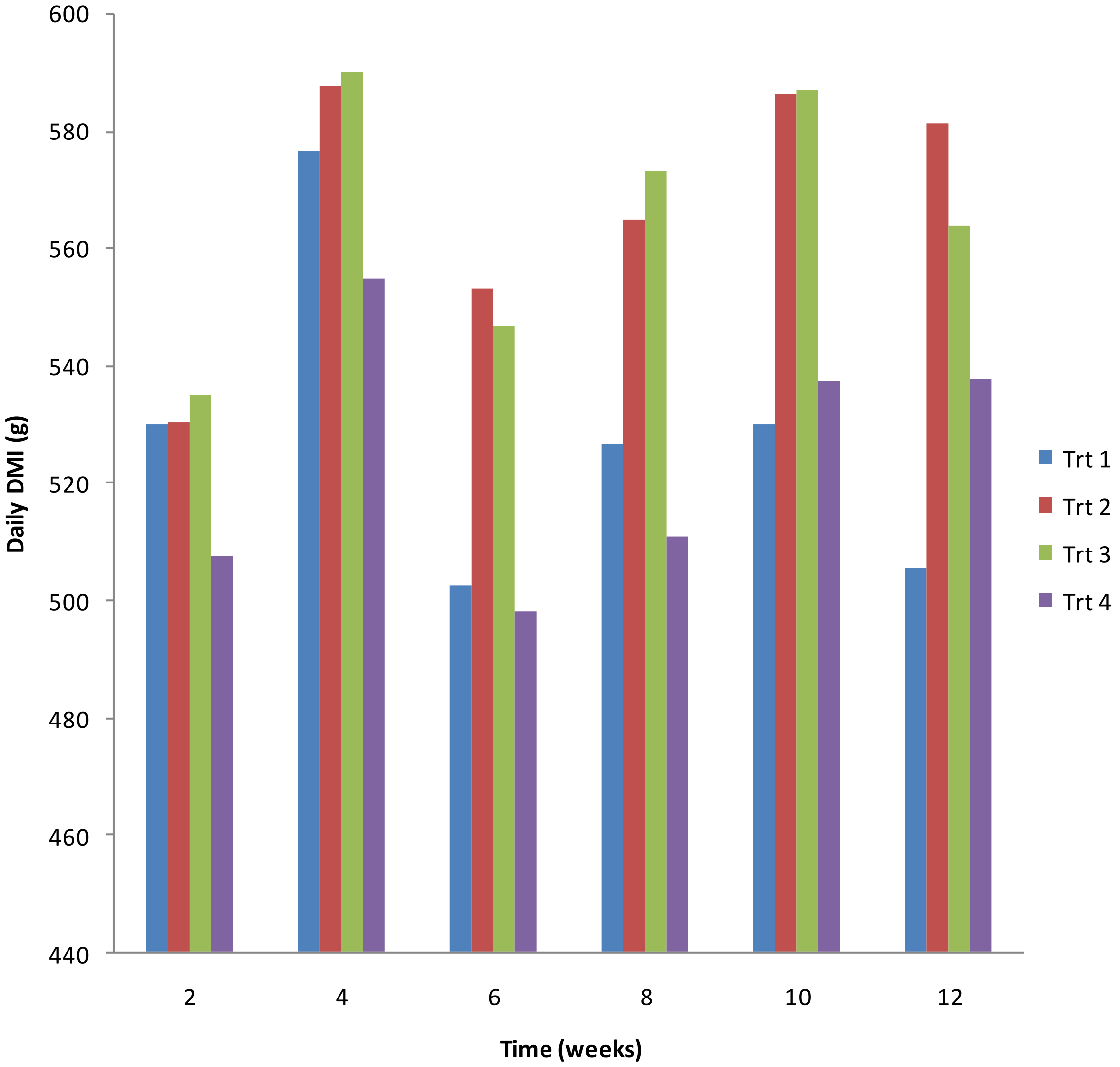

Fig. 4.1 Dry matter intake of feed by Yankasa weaner rams over time

Trt 1: CS fed 1 h prior to feeding grass hay

Trt 2: CS fed 2 h prior to feeding grass hay

Trt 3: Grass hay fed 1 h prior to feeding CS

Trt 4: Grass hay fed 2 h prior to feeding CS

The total weight gain of animals which received grass hay 2 h prior to receiving CS (Trt 4) was significantly higher (60.69 %, $P < 0.05$) than total weight gain of those given CS 1 h prior to feeding grass hay (Trt 1).

Average daily gain of the rams in this study ranged from 10.26 g/d for animals in treatment 1 (CS fed 1 h prior to feeding grass hay) to 31.13 g/d for treatment 4 (grass hay fed 2 h prior to feeding CS) animals. Feeding sequence had no significant ($P > 0.05$) influence on the ADG of the animals. Weaner rams offered CS prior to feeding grass hay had lower ADG (29.52 %) than those fed grass hay before CS. However, Effect of increasing the interval of offering the feeds from 1 h to 2 h on the ADG of the animals was significant ($P < 0.05$). Animals which received the second feed at 2 h interval gained more (43.12 %) weight than those receiving the second feed at 1 h interval. Increasing feeding interval to 2 h increased the ADG of weaner rams by 24.35 % when the grass hay was given before CS ($P > 0.05$), while the corresponding response when CS was fed before grass hay was an increase of 63.72 % with tendency ($P = 0.08$) towards significance.

Fig. 4.2 shows the mean liveweight over time of the animals throughout the experimental period. There was a linear increase in the mean liveweight of all the weaner rams used in this study over the period of experiment. However, the animals in treatment 1 (received CS 1 h prior to feeding grass hay) and those in treatment 3 (given grass hay 1 h prior to receiving CS) showed a decrease in the mean liveweight in the 4th and 12th weeks, with the decrease at the latter still higher than the initial weights at week 2.

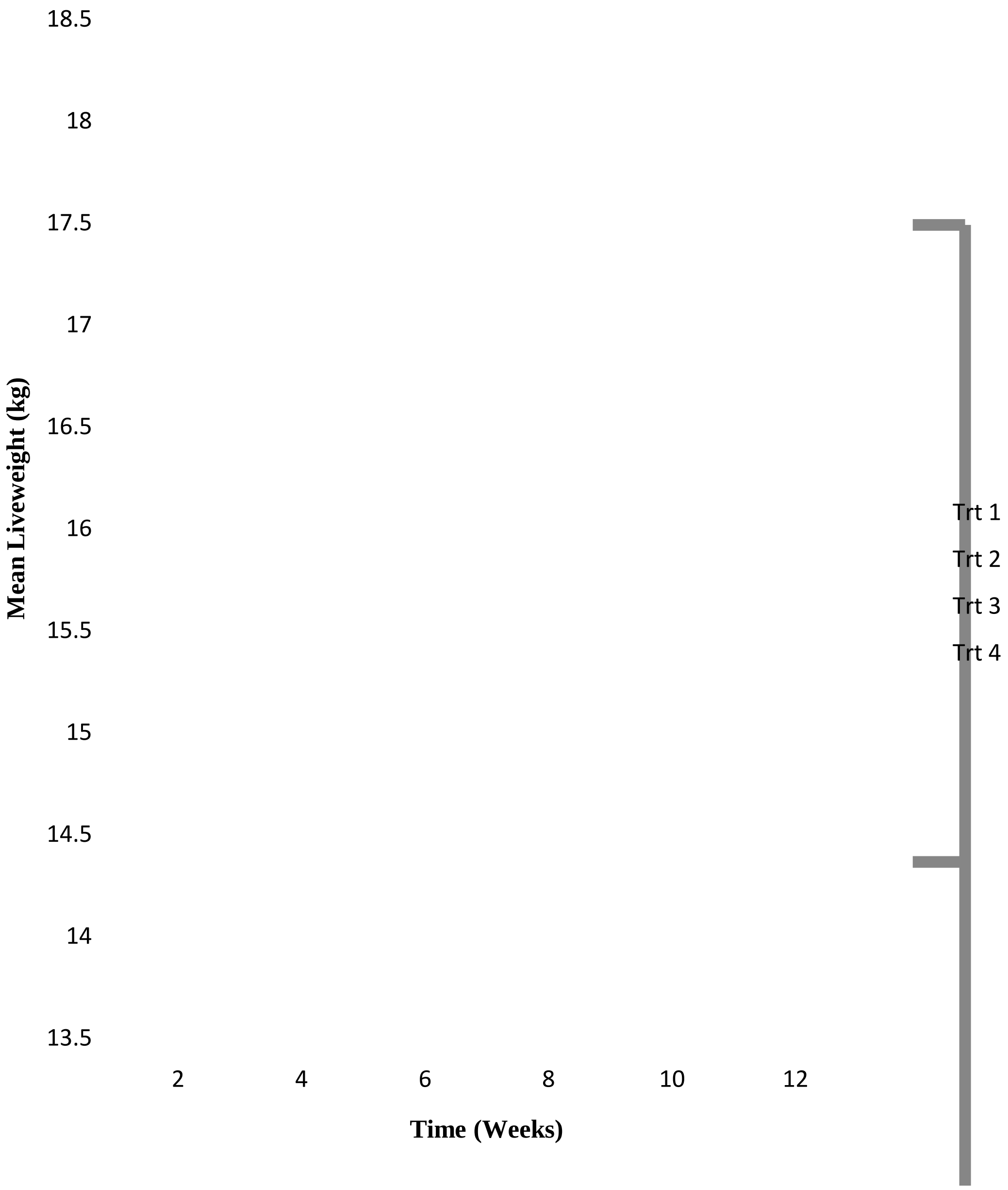

Fig. 4.2 Mean liveweight of Yankasa weaner rams over time

Trt 1: CS fed 1 h prior to feeding grass hay

Trt 2: CS fed 2 h prior to feeding grass hay

Trt 3: Grass hay fed 1 h prior to feeding CS

Trt 4: Grass hay fed 2 h prior to feeding CS

4.1.4 Feed Efficiency

The feed efficiency (Table 4.2) of the rams, which ranged from 18.29 to 57.39 g gain/kg of feed in treatment 1 (received CS 1 h prior to feeding grass hay) and treatment 4 (grass hay fed 2 h prior to feeding CS), respectively, was not affected by changing the feeding sequence. Feeding grass hay before CS increased the feed efficiency by 20.55 %. However, this difference was not significant ($P > 0.05$). The animals given the second feed at 2 h interval had significantly ($P < 0.05$) higher (52.33 %) efficiency than the animals given the second feed at 1 h interval. The feeding sequence x time interval interaction had a significant ($P < 0.05$) influence on the feed efficiency. For example, efficiency was increased by 67.08 % ($P = 0.06$) when CS was fed at 2 h before feeding the grass hay, and by 38.07 % ($P > 0.05$) when grass hay was fed at 2 h before feeding concentrate. Feed efficiency of weaner rams given grass hay 2 h prior to being offered CS (Trt 4) was significantly higher (68.13 %, $P < 0.05$) than that of those given CS 1 h prior to feeding grass hay (Trt 1).

4.1.5 Rumen Metabolites

Table 4.3 shows the influence of sequence and time interval of feeding CS and grass hay on the mean concentrations (before feeding and 3 h after offering the second feed) of ruminal total volatile fatty acids (VFAs), rumen ammonia-nitrogen (NH_3-N) and rumen pH. The highest mean total VFAs values before feeding (23.41 mmol/l) and 3 h after the second feed was given (30.10 mmol/l) were recorded in treatment 4 (grass hay fed 2 h prior to feeding CS). Rams in treatment 2 (CS fed 2 h prior to feeding grass hay) had the least mean total VFAs value (20.57 mmol/l) before feeding, while those in treatment 3 (grass hay fed 1 h prior to feeding CS) had the least mean total VFAs value (23.43 mmol/l) 3 h after feeding the second feed.

Table 4.3. Influence of sequence and feeding interval of concentrate supplement and roughage on rumen pH and metabolites of Yankasa weaner rams

	Feeding sequence							
	Concentrate before grass		Grass before concentrate			Level of significance		
Parameters	1hr (T1)	2hrs (T2)	1hr (T3)	2hrs (T4)	SEM	FS	FI	Interaction
Total VFAs (mmol/L)								
Before feeding	22.29	20.57	21.71	23.41	2.21	NS	NS	NS
3 h after second feeding	25.14	29.71	23.43	30.10	2.0	NS	*	*
NH_3-nitrogen (mg/dl)								
Before feeding	6.58	7.29	7.73	8.00	0.89	NS	NS	NS
3 h after second feeding	6.93	8.18	8.27	7.86	0.63	NS	NS	NS
Rumen pH								
Before feeding	7.15	7.15	7.11	7.01	0.09	NS	NS	NS
3 h after second feeding	6.67	6.86	6.70	6.73	0.04	NS	*	**

VFAs=volatile fatty acids, NH_3=ammonia, SEM=standard error of means, NS=not significant ($P > 0.05$)
*= significant at ($P < 0.05$)   **= significant at ($P < 0.01$)
FS = feeding sequence, FI = feeding interval

The mean values of total ruminal VFAs before and 3 h after feeding the second feed were not affected ($P > 0.05$) by changing the sequence of feeding grass hay and CS. However, the total VFA values at 3 h after giving the second feed were significantly ($P < 0.05$) affected when the interval of sequence of feeding was increased from 1 h to 2 h. For example, the animals given CS and grass hay at 2 h interval had their total VFA in value greater by as much as 18.79 % ($P < 0.05$) compared to those fed CS and grass hay at 1 h interval. The mean concentrations of total VFAs 3 h after the second feed was offered, were influenced ($P < 0.05$) by the sequence x time interval interaction. For instance, at 2 h feeding interval, the mean total VFAs concentrations increased ($P < 0.05$) by 22.16 % when grass hay was fed before CS, while the corresponding response when CS was offered before grass hay was an increase ($P > 0.05$) of 15.38 %.

The mean rumen NH_3-N concentrations (Table 4.3) of the rams used in this study ranged from 6.58 mg/dl to 8.00 mg/dl before feeding for rams in treatments 1 (CS fed 1 h prior to feeding grass hay) and 4 (grass hay fed 2 h prior to feeding CS), respectively, and ranged from 6.93 mg/dl to 8.27 mg/dl 3 h after offering the second feed for rams in treatments 1 (CS fed 1 h prior to feeding grass hay) and 3 (grass hay fed 1 h prior to feeding CS), respectively. Neither significant ($P > 0.05$) effects of the sequence and interval of feeding CS and grass hay, nor those of their interactions were observed on the mean rumen NH_3-N concentrations of the weaner rams.

Also, the mean rumen pH values (Table 4.3) of the rams used in this study, before feeding, ranged from 7.01 to 7.15 for rams in treatments 4 (grass hay fed 2 h prior to feeding CS) and 1 (CS fed 1 h prior to feeding grass hay), respectively. No significant differences ($P > 0.05$) due to effect of the sequence, interval of feeding or their interactions were observed in mean pH values before feeding. However, the interval of feeding CS and grass hay had significant ($P < 0.05$) effect on mean pH values 3 h after offering the second feed. For instance, rams fed CS and grass hay at 2 h interval had their mean rumen pH value greater by 1.62 % ($P < 0.05$) than those fed CS and grass hay at 1 h interval. In addition, there was significant ($P < 0.01$) influence of the sequence x interval interaction on mean rumen pH values of rams 3 h after offering the second feed. For example, at 2 h interval, the mean rumen pH value rose by 2.77 % when CS was offered before feeding grass hay, and rose by 0.45 % when grass hay was fed before giving CS.

Three hours after giving the second feed, the mean rumen pH value (6.86) of animals in treatment 2 (CS 2 h before feeding grass hay) was significantly higher ($P < 0.01$) than the mean pH values (6.67 and 6.70) of animals in treatments 1 (CS 1 h before feeding grass hay) and 3 (grass hay 1 h before offering CS), respectively, but tends towards significance ($P = 0.06$) with the mean pH value (6.73) of treatment 4 (grass hay 2 h before offering CS) animals.

4.1.6 Blood Metabolites

The mean blood glucose levels before feeding (Table 4.4) ranged from 3.65 mmol/l to 4.02 mmol/l for animals in treatment 1 (CS 1 h before feeding grass hay) and treatment 3 (grass hay 1h before feeding CS), respectively, and ranged from 4.02 mmol/l for treatment 1 animals to 4.27 mmol/l for treatment 2 (CS 2 h before feeding grass hay) animals, four hours after the second feed was given.

Also, the mean BUN level was lowest (2.41 mmol/l) for treatment 2 animals and highest (3.12 mmol/l) for treatments 3 and 4 animals. Four hours after offering the second feed, treatment 3 animals had the greatest mean BUN level (2.69 mmol/l), while treatment 2 animals had the least mean BUN level (2.08 mmol/l).

Table 4.4. Blood metabolites of Yankasa weaner rams as affected by sequence and feeding interval of concentrate supplement and roughage

	Feeding sequence					Level of significance		
	Concentrate before grass		Grass before concentrate					
Parameters	1hr (T1)	2hrs (T2)	1hr (T3)	2hrs (T4)	SEM	FS	FI	Interaction
Blood glucose(Mmol/l)								
Before feeding	3.65	3.83	4.02	3.69	0.11	NS	NS	*
4 h after second feeding	4.02	4.27	4.19	4.11	0.10	NS	NS	NS
BUN (mmol/l)								
Before feeding	2.47	2.41	3.12	3.12	0.30	NS	NS	NS
4 h after second feeding	2.36	2.08	2.69	2.44	0.30	NS	NS	NS
Protein (g/l)								
Before feeding	67.08	67.58	67.99	67.46	1.47	NS	NS	NS
4 h after second feeding	68.60	69.31	69.12	68.13	1.73	NS	NS	NS
Creatinine (µmol/l)								
Before feeding	87.29	86.38	93.17	100.00	4.41	NS	NS	NS
4 h after second feeding	88.59	89.67	92.01	102.23	3.49	NS	*	*

BUN=blood urea nitrogen, SEM=standard error of the means, NS=not significant ($P > 0.05$)
*= significant at ($P < 0.05$)
FS = feeding sequence, FI = feeding interval

The mean blood protein levels before feeding ranged from 67.08 g/l to 67.99 g/l for treatments 1 and 3 animals, respectively, and ranged from 68.13 g/l to 69.31 g/l for animals in treatments 4 and 2, respectively, 4 h after giving the second feed. Greatest (100.00 µmol/l) and lowest (86.38 µmol/l) mean blood creatinine levels before feeding were recorded in treatments 4 and 2 animals, respectively. But 4 h after feeding second feed, the highest mean blood creatinine level (102.23µmol/l) was observed in treatment 4 animals and the lowest (88.59 µmol/l) in treatment 1 animals.

The effect of changing the feeding sequence of grass hay and CS was not significant ($P > 0.05$) on blood glucose, blood urea nitrogen (BUN), protein, and creatinine levels before feeding and 4 h after the second feed was offered. For instance, animals fed CS before offering the grass hay had lower mean blood glucose levels (2.86 % and 0.24 %), lower mean BUN levels (21.80 % and 13.62 %), lower and higher mean blood protein levels (0.58 % and 0.46 %), and lower mean blood creatinine levels (10.09 % and 8.23 %), before and 4 h after feeding, respectively, than the animals given the grass hay before offering the CS.

Only the blood creatinine levels 4 h after giving the second feed were significantly influenced by the interval of feeding CS and grass hay. Offering the feeds at 2 h interval increased the blood glucose level by 1.91 % ($P > 0.05$), decreased BUN level by 10.32 % ($P > 0.05$), reduced blood protein level by 0.20 % ($P > 0.05$), and increased the blood creatinine level by 0.06% ($P < 0.05$). There was a significant ($P < 0.05$) interaction between the feeding sequence and time interval in the blood glucose levels before feeding, and in blood creatinine levels 4 h after the second feed was given. For example, before feeding at 2 h interval, the mean blood glucose level of the weaner rams decreased by 8.21 % ($P < 0.05$) when grass hay was fed before CS, but increased by

4.70 % ($P > 0.05$) when CS was fed before the grass hay. Likewise, the mean blood creatinine level rose by 10 % ($P < 0.05$) when grass hay was offered 2 h before giving CS and rose by 1.2 % ($P > 0.05$) when CS was given 2 h before offering the grass hay.

Moreover, in Table 4.4, the animals fed grass hay 2 h before giving CS (trt 4) had higher blood creatinine levels (10 % and 13.34 %, $P < 0.05$), 4 h after the second feed was offered, than the animals fed grass hay 1 h before feeding CS (trt 3) and the animals given CS 1 h before grass hay was fed (trt 1), respectively. The creatinine levels 4 h after giving the second feed show that the differences (12.29 %) between weaner rams which received grass hay 2 h prior to feeding CS (trt 4) and those fed CS 2 h prior to offering grass hay (trt 2) tend towards significance ($P = 0.07$) (Table 4.4).

4.2 METABOLISM TRIAL

4.2.1 Nutrient Intake

The intake of OM (Table 4.5) ranged from 485.46 g/d to 558.21 g/d and that of CP from 66.40 g/d to 76.83 g/d for animals in treatments 1 and 2, respectively. While the ADF intake ranged from 168.97 g/d to 199.06 g/d, and NDF intake ranged from 323.41 g/d to 371.67 g/d for animals in treatments 3 and 2, respectively. Highest intakes of EE (53.60 g/d) and NSC (43.24 g/d) were observed for animals in treatment 2, while lowest intakes of EE (46.37 g/d) and NSC (37.31 g/d) were observed for animals in treatment 1. The intake of nutrients (Table 4.5) by Yankasa weaner rams was not affected ($P > 0.05$) by changing the sequence of feeding CS and grass hay. The animals given CS before the grass hay had numerically greater intake of all nutrients than those fed grass hay before CS. Increasing the feeding interval of grass hay and CS from 1 h to 2 h had a significant ($P < 0.05$) influence on the intake of nutrients.

Table 4.5. Effect of sequence and feeding interval of concentrate supplement and roughage on mean daily nutrient intake of Yankasa weaner rams

	Feeding sequence							
	Concentrate before grass		Grass before concentrate			Level of significance		
Parameters (g/d)	1hr (T1)	2hrs (T2)	1hr (T3)	2hrs (T4)	SEM	FS	FI	Interaction
DM	549.12	631.83	559.38	561.08	58.73	NS	*	*
OM	485.46	558.21	492.71	495.02	51.61	NS	*	*
CP	66.40	76.83	69.76	69.02	7.20	NS	*	*
EE	46.37	53.60	48.46	48.06	5.01	NS	*	*
NDF	325.19	371.67	323.41	326.85	34.31	NS	*	*
ADF	174.59	199.06	168.97	173.45	18.72	NS	*	*
NSC	37.31	43.24	39.51	38.96	4.07	NS	NS	*

OM=organic matter, CP=crude protein, NDF=neutral detergent fibre, ADF=acid detergent fibre, EE=ether extract, NSC=non-structural carbohydrate
SEM=standard error of the means, NS=not significant (P > 0.05)
*= significant at (P < 0.05)
FS = feeding sequence, FI = feeding interval

For instance, OM intake increased by 7.13 % ($P < 0.05$), CP intake by 6.65 % ($P < 0.05$), NDF intake by 7.15 % ($P < 0.05$), ADF intake by 7.77 % ($P < 0.05$), EE intake by 6.73 % ($P < 0.05$) , and NSC intake by 6.55 % ($P = 0.06$) when the time interval of feeding CS and grass hay was extended from 1 h to 2 h.

Also, the effect of interaction between the feeding sequence and time interval on the nutrients intake was significant ($P < 0.05$). For example, the OM intake (Table 4.5) was greater by 13.03 % ($P < 0.05$) when animals were fed CS 2 h prior to feeding grass hay and by 0.47% ($P > 0.05$) when the grass hay was offered 2 h prior to feeding CS. Intake of ADF and NDF followed similar trend, while the values of intake of CP, EE and NSC were lower when the grass hay was fed 2 h before feeding CS. The animals fed CS 2 h prior to feeding grass hay (treatment 2) had higher ($P < 0.05$) intake of all nutrients than the animals given CS 1 prior to feeding grass hay (treatment 1) but had similar intake of all nutrients with treatments 3 and 4 animals.

4.2.2 Apparent Nutrient Digestibility

Table 4.6 shows the digestibility coefficient values of nutrients of Yankasa weaner rams. The apparent digestibility of nutrient was not affected ($P > 0.05$) by the sequence of feeding CS and grass hay. Feeding grass hay before offering CS resulted in a numerical increase in apparent digestibility of DM, OM, EE and NDF, but a numerical decrease in apparent digestibility of CP, ADF and NSC. Similarly, feeding time interval had no significant ($P > 0.05$) influence on the apparent digestibility of the nutrients. Animals given CS and grass hay at 2 h interval had numerically higher digestibility coefficient values for all nutrients than those fed CS and grass hay at 1 h interval. There was no interaction ($P > 0.05$) in apparent digestibility of nutrients between the feeding sequence and feeding interval.

Table 4.6. Influence of sequence and feeding interval of concentrate supplement and roughage on apparent digestibility of nutrients by Yankasa weaner rams

	Feeding sequence					Level of significance		
	Concentrate before grass		Grass before concentrate					
Parameters (%)	1hr	2hrs	1hr	2hrs	SEM	FS	FI	Interaction
DM	60.55	60.47	60.51	61.64	2.09	NS	NS	NS
OM	60.96	61.06	61.59	62.84	3.09	NS	NS	NS
CP	63.42	62.61	59.32	61.54	1.95	NS	NS	NS
EE	61.96	68.77	69.95	66.46	3.63	NS	NS	NS
NDF	61.00	60.89	62.57	63.65	1.97	NS	NS	NS
ADF	51.51	46.94	45.34	50.87	2.91	NS	NS	NS
NSC	51.46	48.81	40.20	53.67	10.61	NS	NS	NS

DM=dry matter, OM=organic matter, CP=crude protein, EE=ether extract, NDF=neutral detergent fibre, ADF=acid detergent fibre, CF=crude fibre, NSC=non-structural carbohydrate, SEM=standard error of the means, NS=not significant ($P > 0.05$).
FS = feeding sequence, FI = feeding interval

The mean digestibility coefficient values for DM, NDF, ADF, CP and NSC were a little higher when grass hay was 2 h before CS but slightly lower when CS was offered 2 h before feeding grass hay. Apparent digestibility of DM, NDF, OM and NSC was slightly greater in treatment 4 (grass hay 2 h prior to feeding CS) than in other treatments. Whereas, in treatment 1 (CS 1 h prior to feeding grass hay) apparent digestibility of ADF and CP was higher than in other treatments. However, the differences were not significant. Generally, the mean of digestibility coefficient values of all nutrients was 62.59% irrespective of the sequence or interval of feeding CS and grass except for ADF and NSC which was 48.60%.

4.2.3 Nitrogen Balance

Total nitrogen intake (Table 4.7) ranged from 11.57 g for animals in treatment 1 (fed CS 1 h before feeding grass hay) to 13.45 g for animals in treatment 2 (fed CS 2 h before feeding grass hay), while nitrogen retention was greatest (2.49 g) and lowest (0.64 g) for animals in treatments 2 and 3 (fed grass hay 1 h before feeding CS), respectively. Changing the sequence of feeding CS and grass hay had no significant ($P > 0.05$) influence on daily intake and retention of nitrogen. When grass hay was offered prior to feeding CS, nitrogen intake was reduced by 1.52 %, nitrogen retention by 32.46 % and per cent nitrogen retention by 48.88 %. In addition, water consumption also decreased by 6.43 % when grass hay was fed before CS. Conversely, extending the feeding interval of CS and grass hay from 1 h to 2 h increased nitrogen intake by 6.25 %, nitrogen retention by 45.34 % and per cent nitrogen retention by 44.85 %, but reduced water intake by 4.14 %. However, these differences were not statistically significant ($P > 0.05$).

Table 4.7. Nitrogen intake and balance and mean daily water intake of Yankasa weaner rams as affected by sequence and feeding interval of concentrate supplement and roughage

	Feeding sequence					Level of significance		
	Concentrate before grass		Grass before concentrate					
Parameters	1hr (T1)	2hrs (T2)	1hr (T3)	2hrs (T4)	SEM	FS	FI	Interaction
Total nitrogen intake (g)	11.57	13.45	12.46	12.19	1.50	NS	NS	NS
Water intake (l)	1.69	1.73	1.69	1.51	0.16	NS	NS	NS
Total urine output (ml)	708.89	746.51	622.43	559.43	120.93	NS	NS	NS
Total faecal output (g)	457.75	547.17	499.92	431.08	66.80	NS	NS	NS
Faecal nitrogen output (g)	8.59	9.68	10.00	8.62	1.65	NS	NS	NS
Urinary nitrogen output (g)	0.93	1.28	1.82	1.11	0.39	NS	NS	NS
Total nitrogen output (g)	9.51	10.96	11.82	9.74	1.70	NS	NS	NS
Nitrogen balance (g)	2.07	2.49	0.64	2.45	0.96	NS	NS	NS
Nitrogen retention (%)	20.91	16.73	-0.69	19.93	8.07	NS	NS	NS

NS=not significant ($P > 0.05$), SEM=standard error of the means.

FS = feeding sequence, FI = feeding interval

Furthermore, the feeding sequence x feeding interval interaction did not affect (P > 0.05) nitrogen intake and retention. The intake of nitrogen was lower (2.17 %) when grass hay was given 2 h before feeding CS, but higher (13.98 %) when CS was offered 2 h before feeding grass hay. Nitrogen intake was least (11.57 g) for animals in treatment 1 (CS 1 h prior to feeding grass hay) and highest (13.45 g) for animals in treatment 2 (CS 2 h prior to feeding grass). Nitrogen retention was highest (2.49 g) in treatment 2 (CS 2 h prior to feeding grass) but lowest (0.64 g) in treatment 3 (grass hay 1 h prior to feeding CS), while per cent nitrogen retention was highest (20.91 %) in treatment 1 (CS 1 h prior to feeding grass) and lowest (-0.69 %) in treatment 3 (grass hay 1 h prior to feeding CS). Although, there are differences in intake and retention of nitrogen among the treatments, they are not statistically significant (P > 0.05).

However, the differences between treatment 1 (CS 1 h prior to feeding grass) and treatment 3 (grass hay 1 h prior to feeding CS) in their mean values for per cent nitrogen retention tend (P = 0.08) towards significance. Water intake, which was highest (1.73 l, P > 0.05) when CS was fed before the grass hay at 2 h interval (trt 2) and lowest (1.51 l) when the grass hay was given before CS at 2 h interval (trt 4), apparently influenced total urine output of the weaner rams used in this study.

CHAPTER FIVE

DISCUSSION

5.1 FEEDING TRIAL

5.1.1 Dry Matter Intake

The highest values of DMI (Table 4.2) recorded for animals in treatment 2 (CS fed 2 h before grass hay) suggests that feeding concentrate mixture 2 h before feeding grass hay impacted most on intake. This might be attributed to the fact that the consumption of concentrate before grass would have sufficiently appetized the gut and provided the required nutrients to enhance microbial growth for the degradation of the feeds. The comparable values of DMI between the sequence of feeding (i.e. whether supplement was fed before or after feeding grass) agrees with the findings of Nocek (1992), Robinson (1994) and Chassaing *et al* (1996) on dairy cow performance fed hay before and after concentrate supplement. It disagrees with those of Morita and Nishino (1991) and Carro *et al* (1994) who recorded higher DMI and OMI respectively, when supplement was fed 1 hour subsequent to hay.

A greater per cent increase in DMI observed when time interval of feeding CS before grass hay was extended from 1 to 2 h, as a result of the sequence x interval of feeding interaction, compared to that of when grass hay was fed before CS at 2 h interval, might be attributed to a sufficient time for degradation of concentrate which resulted in increased rumen microbial population which in turn gave rise to a more rapid degradation of the grass hay, higher digesta passage rate, and less residence time of dry matter in the rumen. An increase in total DMI has been reported to be associated with improved N and energy supply to cellulolytic bacteria, leading to increased degradation of roughage, and to a higher digesta passage rate (Goodchild and McMeniman, 1994; Chakeredza *et al*., 2002)

A cursory look at Figure 4.1 shows that after 4 weeks on the diet, the animals appeared to generally maintain constant DMI over time except for the depression in week 6. The depression is difficult to explain because the animals were fed the same diet and there was no incidence of disease outbreak among the animals. In most cases, overtime, treatments 2 and 3 outperformed other treatments, but the general range of DMI (497.88 to 589.81 g/d) when expressed as % of BW (Table 4.2) meets the generally accepted value of 3% of BW expected to be consumed as DM by growing sheep (Devendra and McLeroy, 1982). The range is comparable to the range of 556 to 582 g/d DMI reported by Olateru and Adegbola (2001) for Yankasa sheep of an average liveweight of 18 kg fed sorghum stover as basal diet.

5.1.2 Liveweight Changes

In this study, all the animals gained weight. The treatment 4 had higher total weight gain than treatment 1, but comparable to treatment 2. Also, average daily weight gain (g/d) followed the same pattern. This observation might be attributed to more efficient utilization of absorbed nutrients by the group fed grass hay 2 h prior to CS. French and Kennelly (1990) have reported improved daily gains and food conversion efficiencies when concentrate was given 1 h after hay. This observation also supports that of Robinson (1994) who reported that numerical differences in weight changes favoured feeding concentrate subsequent to forage-based mixed ration. It, however, disagrees with the conclusion that milk production, and milk fat concentration of dairy cow was not modified by changing the sequence of feeding concentrate and roughage (Nocek, 1992; Chassaing *et al*., 1996). A possible explanation for increased final weight gain recorded for rams receiving CS prior to feeding grass hay, at 2 h feeding interval, compared to rams receiving grass hay before CS was offered, which resulted from the interaction of the sequence and interval of feeding, could be better synchronized nutrients availability which enhances optimal ruminal fermentation, increases microbial protein synthesis and nutrient uptake, and improves growth rate. It has been reported (Sinclair *et al*., 1993; Witt *et al*., 1997; Chumpawadee *et al*., 2004) that synchronized rate of carbohydrate and protein availability in the rumen was beneficial in increasing microbial protein synthesis and growth rate in lambs.

A glance at Figure 4.2 reveals a linear increase in the mean liveweight of all weaner rams used in this study over the period of experiment. However, a slight decrease in mean liveweight in the 4^{th} and 12^{th} week was apparent in treatment 1 (received CS 1 h prior to feeding grass hay) and treatment 3 (given grass hay 1 h prior to receiving CS) animals. The loss in body weight in the 4^{th} week was not expected because total intake values of DM were higher for all treatments during this period. However, the decrease in mean liveweight observed in the 12^{th} week could be explained by the reduction in DM intake that occurred during this week as evident in Figure 1.

5.1.3 Feed Efficiency

The greatest feed efficiency recorded in this study was in treatment 4 (that received grass hay 2 h before CS). This might attributed to the right particle size attained in the grass hay fed to the animals in this group which allows the feed to stay longer in the rumen and be more efficiently digested. Illius and Gordon (1991) reported that food that stays longer in the rumen is more efficiently digested. In addition, the interaction between the sequence and interval of feeding CS and grass hay led to higher feed efficiency in rams that received CS 2 h before grass hay was fed than in those that received grass hay 2 h before CS was fed. This observation might be because of enhanced optimal ruminal fermentation, increased microbial protein synthesis and uptake of available nutrient for rapid multiplication of degradative microbes on concentrate supplement diet prior to grass. Highly synchronous dietary nutrients enhance optimal ruminal fermentation, net microbial protein synthesis and nutrient uptake (Chumpawadee *et al*., 2006).

5.1.4 Rumen Metabolites

5.1.4.1 Rumen VFAs Concentration

The volatile fatty acids production in the rumen is the primary source of metabolisable energy for the ruminant animals (Sastradipradja, 1998). Irrespective of the sequence of feeding, animals receiving the second feed (concentrate or grass) two hours after the first feed (concentrate or grass) had higher concentration of total VFA in the rumen 3 h after feeding the second feed (Table 4.3). This indicates that sufficient time is needed for degradation of the feed through enhanced production of rumen microbes as probably the case in treatment 2 where feeding concentrate mixture first would have increased microbial population in readiness for degradation of grass hay fed 2 h later. Also, longer time for degradation of grass hay in treatment 4, before concentrate was offered 2 hours later, might have resulted in increase in molar proportion of acetic acid before the additive effect of degradation of a relatively degradable feed, the concentrate.

The influence of the sequence x interval of feeding interaction on total VFA concentration, 3 h after feeding the second feed, which was seen to be higher when grass hay was offered 2 h before CS compared to when CS was fed 2 h before grass hay, might be attributable to longer residence time of the grass hay in the rumen. This enabled the rumen microbes to degrade the grass hay more effectively and to attain reduced particle size, which led to more rapid production of VFAs at this period (3 h after feeding the second feed).

5.1.4.2 Rumen Ammonia Nitrogen

Neither the main effects of sequence or interval of feeding CS and roughage nor their interaction significantly influenced rumen ammonia nitrogen concentration pre feeding and 3 h post feeding. However, a close look at Table 4.3 shows that the pattern of rumen NH_3-N production was dependent on the pattern of intakes of hay, concentrate and total DMI where increased intake of protein from concentrate component of the diet was associated with higher concentration of NH_3-N in the rumen. Dietary protein level or intake has been reported to have effect on rumen NH_3-N level (Arroquy *et al.*, 2004). Ammonia is the nitrogen source of main microbes in the rumen (Bandle and Gupta, 1997) and NH_3-N concentration is an indicator of degradation and utilization of nitrogen source by rumen microbes (Wang *et al.*, 2008). In this study, NH_3-N concentration ranged from 6.58 to 8.27 mg/dl. This is above the 5 mg/dl reported to be possible minimal concentration for optimum microbial protein synthesis (Satter and Slyter, 1974). This implies that NH_3-N is unlikely to be a limiting factor for microbial synthesis.

5.1.4.3 Rumen pH

Although the effect of time interval of feeding was significant only between treatments whose animals received concentrate before grass hay, generally, the pH values after feeding the second feed were comparable to the range of 6.2 – 6.8 reported to be favourable for optimal cellulolytic activities by rumen microbes (Ishler *et al*., 1996; Enemark *et al*., 2002). The pH values were apparently a reflection of the pattern of production of total VFAs in the rumen (Table 4.3) with the treatments (2 and 4) with the highest values of total VFAs having the highest values of rumen pH. A look at Table 4.5 shows that animals in these treatments had the most intake of NDF. It is not clear whether a probable higher molar proportion of acetic acid elicited by these treatments might have influenced the rumen pH. It is however known that the more the molar proportion of acetic acid in the rumen the more the rumen pH tends towards alkalinity. The significant rise, 3 h after offering the second feed, in rumen pH value of the rams given CS 2 h prior to feeding grass hay, as compared to the rise in pH value of the rams offered grass hay 2 h prior to feeding CS could be attributed to higher rumen NH_3-N concentration. Increased nitrogen catabolism results in higher rumen NH_3-N which in turn affects rumen pH value (Wang *et al*., 2008).

5.1.5 Blood Metabolites

5.1.5.1 Blood glucose

There was no significant difference in 4 h post feeding blood glucose concentration among the treatments. The comparable values of serum glucose levels three hours after feeding the second feed showed that irrespective of the sequence or time interval of feeding investigated in this study, the production of the required substrate in the rumen for glucose production through gluconeogenesis in the liver was not impaired or limiting. However, the pre feeding concentration was significantly higher (4.02 mmol/L) in the animals in treatment 3 than in animals in treatment 4 (3.69 mmol/L), but statistically similar to 3.83 mmol/L and 3.65 mmol/L of animals in treatments 2 and 1, respectively. This might likely be due to higher pre feeding metabolic activity (gluconeogenesis) of animals in treatment 3. The blood glucose value of 3.65-4.27 mmol/L (65.7-76.86 mg/dl) observed in this study was within the normal blood glucose range (50-80 mg/dl) of sheep reported by Kaneko (1989), Meyer and Harwey (2004), Dhanotiya (2004) and Khaki and Atyabi (2005). Reduced blood glucose level, before feeding, of rams fed grass hay 2 h before CS was offered, as opposed to the increase in blood glucose level of rams given CS 2 h before grass hay, might probably be due to reduced gluconeogenesis because the grass stayed longer in the rumen to allow more efficient fermentation and production of more VFAs as source of energy.

5.1.5.2 Blood Urea Nitrogen

There was no significant difference in BUN concentrations of the animals used in this study, either before feeding or 4 h post feeding. However, the pre-feeding levels of the BUN were observed to be higher than the post-feeding levels. This might probably be because after feeding more of rumen NH_3-N is utilized in the synthesis of microbial protein as a result of rapid increase in microbial population. But as the digesta flows to the abomasum, rumen microbial population decreases and less of rumen ammonia is used, therefore, more of excess ammonia is converted into urea which led to greater pre-feeding BUN concentrations in the blood. The BUN value of 2.36-3.12 mmol/l (14.16-18.72 mg/dl) obtained was within the normal range of 8-20 mg/dl reported for sheep (Kaneko, 1989; Mojabi, 2000; Kabir and Pazdeh, 2002; Banerjee, 2007). This implies adequate dietary protein intake, efficient utilization of dietary protein and absence of renal and liver diseases. Treatment 2 with the lowest BUN concentrations (Table 4.4) had the greatest nitrogen retention (Table 4.7) and a slightly lower weight gain (Table 4.2) than treatment 4. The higher weight gain recorded in treatment 4 might be due to greater feed efficiency of treatment 4 animals. Decreased blood urea-N concentrations had been reported (Galbraith and Watson, 1978; Gabr *et al*., 2009) to be associated with increased nitrogen retention and efficient conversion of feed to liveweight gain.

5.1.5.3 Blood Serum Total Protein

Also, there were no significant differences in blood serum total protein concentrations, either pre feeding or 4 h post feeding, among the animals used in this study. The total protein value of 67.08-69.31 g/l (6.7-6.9 g/dl) recorded was also within the normal range of 5.97-8.23 g/dl reported for sheep (Kaneko, 1989; Mojabi, 2000; Kabir and Pazdeh, 2002; Meyer and Harwey, 2004). Higher mean liveweight gain was expected in treatment 2 than in treatment 4 because of greater serum total proteins level observed in treatment 2. Increase in body weight was attributed to the increase in serum total proteins (Gabr *et al*., 2009).

5.1.5.4 Blood Creatinine

The blood creatinine level of animals in treatment 4 was significantly higher (102.23 µmol/L) than those of animals in treatments 1 and 3 (88.59 µmol/L and 92.01 µmol/L, respectively.), and tend to be higher than that of animals in treatment 2 (89.67 µmol/L). The value of 86.38-102.23 µmol/L (0.98-1.16 mg/dl) obtained in this study was within the normal range of blood creatinine (0.9-2 mg/dl) reported by Kabir and Pazdeh (2002), and 0.89-1.32 mg/dl reported by Mojabi (2000), but a little lower than 1.2-1.9 mg/dl reported by Kaneko (1989) and Meyer and Harwey (2004). This result is indicative of good metabolism of dietary protein and amino acids in building body mass by the animals used in this study. The greater mean blood creatinine level observed in treatment 4 (Table 4.4) may be due to higher weight gain recorded for treatment 4 animals (Table 4.2). Elevated concentrations of creatinine in the serum have been attributed to the influence of large muscular mass (Zvonko *et al*., 2008). Furthermore, higher per cent increase in blood creatinine level was expected when CS was fed 2 h prior to feeding grass hay than when grass hay was fed 2 h prior to feeding CS, in order to correspond to greater per cent weight gain. According to Hatfield *et al*., (1998), creatinine is a product of nitrogen metabolism related to muscle contraction and its synthesis rate may be considered an index of endogenous protein catabolism.

5.2 METABOLISM TRIAL

5.2.1 Nutrient Intake

Among the animals fed concentrate mixture before grass hay, the intake of all the nutrients (OM, CP, NSC, ADF, NDF and EE) was significantly higher for animals fed concentrate mixture 2 h before grass than those fed 1 h before grass hay. Although not significant, the intake values of nutrients were numerically higher for animals in treatment 2 than for animals in treatment 3 and 4. This disagrees with the finding of Carro *et al*. (1994) that animals given concentrate after a period of hay ingestion had higher total organic matter intake than animals fed hay before concentrate. This finding is also not in support of Robinson (1994) who reported that virtually all production parameters favoured feeding grain subsequent to hay. The differences between the observed intake in this study and those of Carro *et al*. (1994) and Robinson (1994) might be due to differences in the interval of feeding concentrate and roughage employed. For instance, Carro *et al*. (1994) fed concentrate either 30 min before giving hay or 1 h after hay was fed, while Robinson (1994) fed concentrate 1 h before and after hay was offered. Whereas in this study the interval of feeding concentrate was increased to 2 h prior or subsequent to hay. Possibly 30 min or 1 h was too short a time for animals fed concentrate to optimally degrade the concentrate before intake of hay. In addition, the differences between the species of animals used, and diets fed in this study and their own might also be responsible for this disagreement in observations.

5.2.2 Apparent Nutrient Digestibility

Apparent nutrient digestibility was not affected by either individual effect of sequence and interval of feeding concentrate and roughage or by their combined effects. This observation is in harmony with the conclusion of Carro *et al*. (1994) that time interval of supplementation did not significantly affect the apparent digestibility of OM. From the result in this study, apparent digestibility of NDF, NSC, OM and DM (Table 4.6) was numerically higher for the animals in treatment 4 (grass hay fed 2 h before giving CS). This may explain higher overall weight gain and higher ADWG recorded for animals in treatment 4 (Table 4.2).

5.2.3 Nitrogen Balance

There were no significant differences among the treatments in the intake, faecal and urinary excretion, and retention of nitrogen. Per cent nitrogen retention of animals in treatment 1 (20.91%) tends to be higher than per cent nitrogen retention of animals in treatment 3 (-0.69 %). All animals were in positive nitrogen balance. This indicates that the lambs received adequate amounts of nitrogen from the diets fed. Water intake was also not affected by the sequence and interval of feeding CS and hay. Numerically higher mean value (1.73 l/d) of water intake was recorded for animals in treatment 2 than for animals in other treatments (1.69 and 1.51 l/d). This study was conducted during wet season when the average daily ambient temperature inside the pen used was about 25.5^{o}C. This may account for low water intake by the rams observed (Aganga *et al*., 1988).

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 SUMMARY

The results of feeding trial showed that feeding concentrate supplement 2 h prior to grass hay enhanced the highest total dry matter intake, but nutrients were more efficiently utilized when concentrate supplement was fed 2 h subsequent to grass hay as it was evident in the feed efficiency, final and average daily weight gain of Yankasa weaner rams.

Based on metabolism trial results, numerical differences in apparent digestibility values of DM, OM, NSC and NDF favoured feeding concentrate supplement 2 h subsequent to hay, while numerical differences in nitrogen intake and retention favoured feeding concentrate supplement 2 h prior to grass hay.

6.2 CONCLUSION AND RECOMMENDATION

From the results of this study, it is concluded that feed intake and performance of Yankasa weaner rams were not markedly influenced by the sequence, but by the interval of feeding concentrate supplement and grass hay. However, based on the indices of feed efficiency and average daily gain, it is recommended that, under intensive or semi-intensive management systems and feedlot operations, concentrate supplement be fed 2 h subsequent to grass hay for the attainment of best growth rate and feed efficiency in Yankasa weaner rams. For future studies it is suggested that more time intervals or wider time intervals be investigated in stall-fed or grazed sheep in respect of sequence of feeding concentrate supplement and roughage.

6.3 CONTRIBUTIONS TO KNOWLEDGE

The contributions made to knowledge by this study are as follows:

i. Sequence of feeding concentrate supplement and roughage does not affect performance of Yankasa weaner rams.

ii. Interval of feeding concentrate supplement and roughage has significant influence on performance of Yankasa weaner rams.

iii. For better feed management and utilization, Yankasa weaner rams should be offered concentrate supplement 2 h after feeding grass hay.

REFERENCES

Abdu, S.B., Ehoche, O.W., Adamu, A.M., Bawa, G.S., Hassan, M.R., Yashim, S.M. and Adamu, H.Y. (2012). Effect of Varying Levels of Zizyphus (*Zizyphus mauritiana*) Leaf Meal Inclusion in Concentrate Diet on Performance of Growing Yankasa Ram Lambs Fed Maize Stover Basal Diet. *Iranian Journal of Applied Animal Science* 2(4): 323-330.

Aby, B.A., Aass, L., Sehested, E. and Vangen, O. (2013). Effect of incorporating greenhouse gas emission costs into economic values of traits for intensive and extensive beef cattle breeds. *Livestock science.* Retrieved October 5, 2012, from http://dx.doi.org/10.1016/J.livsci/2013.09.009.

Adama, T.Z. (2008). *Towards adequate animal protein intake by the year 2020*. Inaugural Lecture Presentation, Federal University of Technology, Minna, Nigeria. Series 11, pp: 6-68.

Adamu, A.M., Eduvie, L.O., Ehoche, O.W., Lufadeju, E.A., Olorunju, S.A.S., Okaiyeto, P.O., Hena, S.W., Tanko, R.J., Adewuyi, A.A. and Magaji, S.O. (1993). Effects of nitrogen, energy and mineral supplementation on the growth and reproductive performance of Bunaji heifers grazing native pastures and crop residues. In: Adamu, A.M., Mani, R.I., Osinowo, O.A., Adeoye, K.B. and Ajileye, E.O. (Eds). *Forage Production and Utilization in Nigeria*. Proceedings of Second Livestock Development Project Workshop, Zaria, Nigeria, 11-14 February 1991. NLPD (National Livestock Projects Division), Kaduna, Nigeria. Pp 166-176.

Adegbola, T.A. (1998). *Sustainable ruminant production for human nutrition and national development*. Inaugural Lecture Series, No. 7. University Inaugural Lecture delivered on 21st January, 1998 at A.T.B.U. Bauchi, Nigeria.

Adegun, M.K., Aye, P.A. and Dairo, F.A.S. (2011). Evaluation of *Moringa oleifera*, *Gliricidia sepium* and *Leucaena leucocephela* – based multinutrient blocks as feed supplements for sheep in South Western Nigeria. *Agriculture and Biology Journal of North America* 2(11): 1395-1401.

Ademosun, A.A. (1994). *Constraints and prospects for small ruminant research and development in Africa*. Retrieved February 20, 2012, from http://www.fao.org/wairdocs/ILRI/x5472b/x5472b02.htm

Ademosun, A.A., Bosman, H.G. and Roessen, P.L. (1985). *Nutritional studies with West African Dwarf Goats in the humid zone of Nigeria*. Retrieved October 15, 2014, from http://ilri.org/Infoserv/webpub./fulldocs/x5464b/x5464b00.htm#contents.

Adewumi, O.O. and Olorunnisomo, O.A. (2009). *Milk yield and milk composition of West African dwarf, Yankasa and crossbred sheep in Southwest of Nigeria*. Retrieved February 15, 2014, from http:// www.Irrd.org/irrd21/3/adew21042.htm

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

Aganga, A.A., Umunna, N.N., Oyedipe, E.O. and Okoh, P.N. (1988). Seasonal variations in water requirement and influence of intermittent watering on grazing Yankasa sheep. *Small Ruminant Research* 1:381-386.

Agbede, J.O. and Aletor, V. (2004). Chemical characterization and protein quality evaluation of leaf protein concentrates from *Gliricidia sepium* and *Leucaena leucocephela*. *Journal of Food Science Technology* 39: 253-261.

Ahn, J.H. (1990). Quality assessment of tropical browse legumes: tannin content and nitrogen digestibility. Ph.D. thesis, The University of Queensland, Australia.

Ajayi. H.I., Olomu, J.M. and Oyedeji, J.O. (2008). Potentials of African pear (Dacryodes edulis) as a feedstuff for animals. *Proceedings of the 13th Annual Science Association of Nigeria*, September 15-19, 2008, Zaria, Nigeria.

Akingbamijo, O.O., Adediran, S.A., Nouala, S. and Seeker, J. (2006). Moringa fodder in ruminant nutrition in the Gambia. *Trees for life journal*. Retrieved April 6, 2011, from http://www.tfjournal.org.

Akintunmi, A.H. (2004). Evaluation of sword bean *Canavalia gladiate* as an alternative feed resource for broiler chickens. Ph.D. Thesis, Michael Okpara University of Agriculture Umudike, Nigeria.

Alawa, J.P. and Umunna, N.N. (1993). Alternative feed formulation in the developing countries prospects for utilization of agro-industrial by-products. *Journal of Animal Production Research* 13:63-98.

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

Alhassan, W.S. (1985). The potential of agro-industrial by-products and crop residues for sheep and goats production in Nigeria. *Proceedings of the National Conference on Small Ruminant Production in Nigeria*, October 6-10, 1985, Zaria, Nigeria, pp165-183.

Alhassan, W.S., Ehoche, O.W., Adu, I.F., Obilana, A.T. and Kallah, M.S. (1984). Crop residue potentials of agricultural development projects: (b) nutritive value and residue management. *Annual Report*, National Animal Production Research Institute, Zaria, Nigeria. Pp. 35-45.

Aliyu, M.M., Bukar, M.M. and Zira, A.B. (2005). Occurrence of small ruminant lameness in Maiduguri and its environs. *Sokoto Journal of Veterinary Sciences* 6: 4-6.

Allen, M.S. (1997). Relationship between fermentation acid production in the rumen and the requirement for physically effective fibre. *Journal of Dairy Science* 80: 1447-1462.

Almeida, A.M., Schwalbach, L.M.J., Cardoso, L.A. and Greyling, J.P.C. (2007). Scrotal, testicular and semen characteristics of young Boer bucks fed winter veldt hay: the effect of nutritional supplementation. *Small Ruminant Research* 73: 216-220.

AOAC (2000). Association of Official Analytical Chemists, 17^{th} revised edition. In: *Official methods of Analyses*, Washington DC pp. 210-240.

Aphunu, A. and Okoedo, O.D.U. (2011). Small ruminant production constraints among farmers in Ika north-east local government area of Delta State, Nigeria. *Archives of Applied Science Research* 3(2): 370-376.

Aregheore, E.M. (2004). Intake and digestibility of *Moringa oleifera* – batiki grass mixtures by growing goats. *Small Ruminant Research* 46(1): 23-28.

Aregheore, E.M. (2009). *Country Pasture/Forage Resource Profile, Nigeria.* Food and Agriculture Organization (2009). Viale delle Terme di Caracalla, Rome, Italy. Pp. 17-18.

Arieli, A., Sasson-Rath, R., Zamwel, S. and Mabjeesh, S.J. (2005). Effect of dietary protein and rumen degradable organic matter on milk production and efficiency in heat-stressed goats. *Livestock Production Science* 96: 215-223.

Arroquy, J.I., Cochran, R.C., Villareal, M., Wickersham, T.A., Llewellyn, D.A., Titgemeyer, E.C., Nagaraja, T.G., Johson, D.E. and Gnad D. (2004). Effect of level of rumen degradable protein and type of supplemental non-fibre carbohydrate on intake and digestion of low-quality grass hay by beef cattle. *Animal Feed Science Technology* 115: 83-99.

Aruwayo, A. and Maigandi, S.A. (2013). Neem (*Azadirachta indica*) Seed Cake/Kernel as Protein Source in Ruminants Feed. *American Journal of Experimental Agriculture* 3(3): 482-494.

Ash, A.J. (1990). The effect of supplementation with leaves from the leguminous trees *Sesbania grandiflora*, *Albizia chinensis* and *Gliricidia sepium* on the intake and digestibility of guinea grass hay by goats. *Animal Feed Science Technology* 28:225-232.

Avondo, M., Licitra, G., Bognango, M., Keshtkaran, A.N., Marletta, D. and D'Urso, G. (1995). Effects of the type and level of supplementation on grazing behavior of lactating ewes in a Mediterranean natural pasture. *Livestock Production Science*. 44:237-244.

Aydin, G., Grant, R.J. and ÓRear, J. (1999). Brown midrib sorghum in diets for lactating dairy cows. *Journal of Dairy Science* 82(10): 2127-2135.

Aydin, R., Yanar, M., Kocyight, R., Diler, A. and Ozkilicci, T.Z. (2009). Effect of direct-fed microbial plus enzyme supplementation on the fattening performance of Holstein young bulls at two different initial body weights. *African Journal of Agricultural Research* 4: 548-552.

Aye, P. A. (2012). Production of *Gliricidia* and *Leucaena* – based multi-nutrient blocks as supplementary ruminant feed resource in South Western Nigeria. *Agriculture and Biology Journal of North America* 3(5): 213-220

Aye, P.A. (2007). Production of multinutrient blocks for ruminants and alcohol from waste products of *Leucaena* and *Gliricidia* leaves using local technologies. Ph.D. Thesis, Federal University of Technology, Akure, Nigeria.

Baah, J., Tait, R.M. and Tuah, A.K. (2011). Selecting browse plants to supplement cassava peel-based diet for peri-urban small ruminants. *Small Ruminant Research* 96: 36-40.

Bach, A., Calsamigla, S. and Stern, M.D. (2005). Nitrogen metabolism in the rumen. *Journal of Dairy Science* 88: E9-E21.

Bandle, S. and Gupta, B.N. (1997). Rumen fermentation, bacteria and total volatile fatty acid (TVFA) production rates in cattle fed on urea-molasses-mineral block licks supplement. *Animal Feed Science and Technology* 65: 275-286.

Bandyk, C.A., Cochran, R.C., Wickersham, T.A., Titgemeyer, E.C., Farmer, C.G. and Higgins, J.J. (2001). Effect of ruminal vs postruminal administration of degradable protein on utilization of low –quality forage by beef steers. *Journal of Animal Science* 79: 225-231.

Banerjee, G.C. (2007). *A text book of Animal Husbandry*. 8th ed. Published by Raju Primlani for Oxford and IBH publishing Co. Pvt. Ltd. New Delhi, India. Pp1079.

Bargo, F., Muller, L.D., Delahoy, J.E. and Cassidy, T.W. (2002). Performance of high producing dairy cows with three different feeding systems combining pasture and total mixed rations. J*ournal of Dairy Science* 85: 2948-2963.

Beauchemin, K.A. (1992). The first 100 days of lactation: how to feed for maximum production and keep cows healthy. Pp 28-40 in: Kennelly, J.J. (Ed). *Advances in dairy technology*. Volume 4. Department of Animal Science, university of Alberta, Edmonton, AB.

Beauchemin, K.A. and Buchanan-Smith, J.G. (1990). Effects of fibre source and method of feeding on chewing activities, digestive function, and productivity of dairy cows. *Journal of Dairy Science* 73: 749-762.

Beauchemin, K.A., Kreuzer, M., O'mara, F. and McAllister, T.A. (2008). Nutritional management for enteric methane abatement: a review. *Australian Journal of Experimental Agriculture* 48: 21-27.

Belant, J.L., Kielland, K., Follmann, E.H. and Adams, L.G. (2006). Interspecific resource partitioning in Sympatric ursids. *Ecological Applications*. 16: 2333-2343.

Bello, A.A. and Tsado, D.N. (2013). Feed Intake and Nutrient Digestibility of Growing Yankasa Rams Fed Sorghum Stover Supplemented with Graded levels of dried poultry droppings based diet. *Asian Journal of Animal Science* 7:56-63.

Biu, A.A., Maimunatu, A., Salamatu, A.F. and Aghadu, E.T. (2009). A faecal survey of gastrointestinal parasites of ruminants on the University of Maiduguri Research Farm. *International Journal of Biomedical and Health Sciences* 5(4): 175-179.

Bodine, T.N., Purvis, H.T. and Lalman, D.L. (2001). Effects of supplement type on animal performance, forage intake, digestion, and ruminal measurements of growing beef cattle. *Journal of Animal Science* 79: 1041-1051.

Bohnert, D.W., Schauer, C.S. and Delcurto, T. (2002). Influence of rumen protein degradability and supplementation frequency on performance and nitrogen use in ruminants consuming low-quality forage: cow performance and efficiency of nitrogen use in wethers. *Journal of Animal Science* 80: 1629-1637.

Bouwman, A.F., Van der Hoek, K.W., Eickhout, B. and Soenario, I. (2005). Exploring changes in world ruminant production systems. *Agricultural System* 84:121-153.

Bowman, J.G.P. and Sanson, D.W. (1996). Starch- or fibre-based energy supplements of grazing ruminants. *Proceedings, Western Section, American Society of Animal Science*. 47(1): 118-135.

Bushara, I., Abdel-Moneim, M.A., Nikhaia, A. and Mekki, D.M. (2010). Productive and reproductive traits of Taggar goats as affected by type of ration under dry land farming system in Western Sudan. *Egyptian Journal of Sheep and Goat Science* 5 (1): 209-220.

Carey, D.A., Caton, J.S. and Biondini, M. (1993). Influence of energy source on forage intake, digestibility, in situ forage degradation, and ruminal fermentation in beef steers fed medium-quality brome hay. *Journal of Animal Science* 71: 2260-2269.

Carro, M.D., Mantecon, A.R., Wright, J.A. and Gordon, I.J. (1994). Effect of time supplementary feeding on intake, apparent digestibility and rumen fermentation of grass hay by sheep. *Animal Production* 59: 217-222.

Carro, M.D., Valdés, C., Ranilla, M.J. and Gonzállez, J.S. (2000). Effect of forage to concentrate ratio in the on ruminal fermentation and digesta flow kinetics in sheep offered food at a fixed and restricted level of intake. *Animal Science* 70: 127-134.

Caton, J.S. and Dhuyvetter, D.V. (1996). Manipulation of maintenance requirements with supplementation. In: Judkins, M.B. and McCallum, F.T. III (Ed.), Proceeding 3rd Grazing Livestock Nutrition Conference. *Proceedings, Western Section, American Society of Animal Science.* 47(1): 72.

Caton, J.S. and Dhuyvetter, D.V. (1997). Influence of energy supplementation on grazing ruminants: requirements and responses. *Journal of Animal Science*, 75: 533-542.

Chakeredza, S., Ter-Meulen, U. and Ndlovu, L.R. (2002). Ruminal fermentation kinetics in ewes offered a maize stover basal diet supplemented with cowpea hay, groundnut hay, cottonseed meal or maize meal. *Tropical Animal Health Production* 34:215-230.

Chandrasekharaiah, M., Thulasi, A. and Sampath, K.T. (2012). Effect of different rumen degradable nitrogen levels on microbial protein synthesis and digestibility in sheep fed on finger millet straw (*Eleucine coracana*) based diet. *Small Ruminant Research* 102:151-156.

Chassaing, C., Coulon, J.B., Agabriel, C. and Garel J.P. (1996). The effect of feeding sequence on fat concentration in milk. *Annales De Zootechnie* 45: 151-157.

Chen, X.B., Subba, D.B., Orskov, E.R. and Jayasuriya, M.C.N. (1999). Purine nitrogen index, potentially a new parameter for rapid feed evaluation in ruminants. *IAEA-TECDOC* 109:97-110.

Chisowa, D. M. and Mwenya, J. (2013). Evaluation of *Leucaena Leucocephala, Caliandra Calothyrsus, Gliricidia Sepium and Sesbania Sesban* Leaves as Basal Feeds for Growing Rabbits (*Oryctolagus cunniculus*). *European Academic Research* 1: 1935-1952.

Chumpawadee, S., Sommart, K., Vongpralub, T. and Pattarajinda, V. (2006). Effects of synchronizing the rate of dietary energy and nitrogen release on ruminal fermentation, microbial protein synthesis, blood urea nitrogen and nutrient digestibility in beef cattle. *Asian-Australian Journal of Animal Science* 19(2): 181-188.

Chumpawadee, S., Sommart, K., Vongpralub, T. and Pattarajinda, V. (2004). Effect of synchronizing the rate of dietary energy and nitrogen release on ruminal fermentation, microbial protein synthesis, blood urea nitrogen and nutrient digestibility in beef cattle. *Asian-Australian Journal of Animal Science* 19: 181-188.

Clarence, M.F., Jan, A.B., Asa, M. and Susan, E.A. (1991). *Lameness in sheep and goat in Rahway*. N.J. USA. Pp 503-504.

Coffey, L. (2006). *Meat Goats: Sustainable Production*. ATTRA. Retrieved September 9, 2009, from http://www.attra.org/attra-pub/meatgoat.html.

Cole, N.A. and Todd, R.W. (2008). Opportunities to enhance performance and efficiency through nutrient synchrony in concentrate-fed ruminants. *Journal of Animal Science* 86(E. Suppl.): E318-E333.

Costa, V.A.C., Detmann, E., Valadares Filho, S.C., Paulino, M.F., Henriques, L.T. and Mantovani, H.C. (2008). *In vitro* degradation of low-quality tropical forage neutral detergent fibre according to protein and (or) carbohydrates supplementation. *Brazilian Journal Animal Science* 37: 494-503.

Currier, T.A., Bohnert, D.W., Falek, S.J., Schauer, C.S. and Bartle, S.J. (2004). Daily and alternate day supplementation of urea and biuret to ruminants consuming low-quality forage: 1. Effects on cow performance and the efficiency of nitrogen use in wethers. *Journal of Animal Science* 82: 1508-1517.

DelCurto, T., Cochran, R.C., Harmon, D.L., Beharka, A.A., Jacques, K.A., Towne, G. and Vanzant, E.S. (1990). Supplementation o f dormant tall-grass-prairie forage: I. Influence of varying supplemental protein and (or) energy levels on forage utilization characteristics of beef steers in confinement. *Journal of Animal Science* 68: 515-531.

Detmann, E., Paulino, M.F. and Valadares Filho, S.C. (2008). Avaliação nutricional de alimentos ou de dietas? Uma abordagem conceitual. *Proceedings of 2nd International Symposium on Beef Cattle Production.* Viçosa, Brazil. Pp. 21-52.

Detmann, E., Paulino, M.F., Mantovani, H.C. Valadares-Filho, S.C., Sampaio, C.B., Souza, M.A., Lazzarini, I. and Detmann, K.S.C. (2009). Parameterization of ruminal degradation in low-quality tropical forage using *Michaelis-Menten* Kinetics. *Livestock Science* 126: 136-146.

Devendra, C. (1990). The use of shrubs and tree fodders by ruminants. In: Devendra, C. (Ed.), *Shrubs and Tree Fodders for Farm Animals*. Proceedings of a workshop in Denpasar, Indonesia. IDRC, Ottawa, Canada, pp. 42-60.

Devendra, C. (1996). Use of fodder resources by ruminants in warm climate countries. *Annales De Zootechnie* 45:11-20.

Devendra, C. and Burns, M. (1983). *Goat production in the tropics*. Commonwealth Agricultural Bureau, Slough, UK. Pp 183.

Devendra, C. and Leng, R.A. (2011). Feed resources for animals: Issues, strategies for use, intensification and integration for increased productivity. Invited Review. *Asian-Australian Journal of Animal Science* 24(3): 303-321.

Devendra, C. And McLeroy, G.B. (1982). *Goat and Sheep Production in the Tropics*. International Tropical Agricultural Series. Longman Publishers Limited London, New York, pp 209-210.

Dewhurst, R.J., Davies, D.R. and Merry, R.J. (2000). Microbial protein supply from the rumen. *Animal Feed Science and Technology* 85:1-21.

Dhanotiya, R.S. (2004). *Textbook of veterinary biochemistry*. Jaypee, Noida, India. Pp. 448-449.

Egahi, J.O., Dim, N.I. and Adikwu, O. (2012). Small Ruminant Flock Ownership Pattern in the Guinea Savanna Region of Nigeria. *International Journal of Advanced Biological Research* 2(1):156-158.

Egwu, G.O., Adamu, S.S., Ameh, J.A., Oyeyili, P.A., Abana, S.P., Chaudhri, SU.R. and Rabo, J.S. (1994). Retrospective clinicopathological and microbiological studies of inter digital pouch lameness in sheep in an arid zone of Nigeria. *Bulletin of Animal Health and Production in Africa* 42: 5-11.

Elseed, F.A.M.A. (2005). Effect of supplemental protein feeding frequency on ruminal characteristics and microbial N production in sheep fed treated rice straw. *Small Ruminant Research* 57: 11-17.

Enemark, J.M.D., Jørgensen, R.J. and Enemark, P. (2002). Rumen acidosis with special emphasis o diagnostic aspects of subclinical rumen acidosis: A Review. *Veterinarija Ir Zootechnika. T.* 20(42): 16-29.

FAO, (2006). *Livestock's Long Shadow: Environmental Issues and Options*. Food and Agricultural Organization of the United Nations. Rome, Italy, p. 390.

FAO, (2007). www.faostat.fao.org.

FAO. (2012). Food and Agricultural Organization of United Nations. Retrieved April 15, 2012, from: (http://faostat.fao.org/site/573/default.aspx#ancor).

Fasae, O.A., Adu, I.F. and Aina, A.B.J. (2012). Smallholder sheep feeding based on defoliated cassava and maize leaves. *Tropical and Subtropical Agroecosystems* 15: 557-565.

FMARD, (2002). Field Situation Assessment of Agricultural Production in Nigeria. Study conducted by NAERLS and PCU.

FMAWR, (2008). Federal Ministry of Agriculture and Water Resources, Federal Republic of Nigeria, Draft National Security Programme 107.

Fon, F.N. and Nsahlai, I.V. (2013). Effect of direct-fed microbial consortia on ruminal fermentation of maize stover in sheep. *Small Ruminant Research* 111: 71-75.

French, N. and Kennelly, J.J. (1990). Effects of feeding frequency on ruminal parameters, plasma insulin, milk yield, and milk composition in Holstein cows. *Journal of Dairy Science* 68: 515-531.

Gabr, F. I., Hassan, T.A., Abo El-Maaty, A. M. and Aotifa, A.M.A. (2009). Effects of growth promoter Boldenone undecylenate on weaned male lambs. *Nature and Science* 7(3): 61-69.

Galbraith, H. and Watson, H.B. (1978). Performance, blood and carcase characteristics of finishing steers treated with trenbolone acetate and hexoestrol. *Veterinary Research*. 103(2): 28-31.

Gefu, J.O. (2002). Socio-economic Considerations in Small Ruminant Production. In: Lakpini, C.A.M., Adamu, A.M., Ehoche, O.W. and Gefu, J.O. (Eds). *Manual for Small Ruminant Production in Nigeria*, National Animal Production Research Institute, Ahmadu Bello University, Zaria, Nigeria. Pp.8-11

Goodchild, A.V. and McMeniman, N.P. (1994). Intake and digestibility of low quality roughages when supplemented with leguminous browse. *Journal of Agricultural Science* 122: 151-160.

Groehn, J.A., Kaneene, J.B. and Foster, D. (1992). Risk factors associated with lameness in lactating dairy cattle in Michigan. *Preventive Veterinary Medicine* 14: 77-85.

Habib, W., Basir, A.S., Wahidullah, W and Ghuftmullah. (1991). The importance of urea-molasses blocks and by-pass protein in Animal Production. *The Situation in Pakistan* 135-145.

Hall, M.B. and Huntington, G.B. (2008). Nutrient synchrony: Sound in theory elusive in practice. *Journal of Animal Science* 86: E287-E292.

Hamito, D. (2008). Preface. In: Hirpa, A. and Abebe, G. (Eds.), *Sheep and Goat Production Handbook for Ethiopia*. p5. Retrieved December 18, 2011, from http://www.Inform.und.edu.EdRes.

Hatfield, P.G., Hopkins, J.A., Ramsey, W.S. and Gilmore, A. (1998). Effects of level of protein and type of molasses on digesta kinetics and blood metabolites in sheep. *Small Ruminant Research* 28: 161-170.

Hemingway, R., Parkins, J. and Fraser, J. (1986). A note on the effect of molasses inclusion in sugar beet pulp on the yield and composition of the milk of dairy cows. *Animal Production* 42: 417-420.

Henning, P.A., Van der Linden, Y., Matthorpe, M.C., Nauhaus, W.K. and Swartz, H.M. (1980). Factors affecting the intake and digestion of roughage by sheep fed maize straw supplemented with maize grain. *Journal of Agricultural Science* 94: 565.

Hersom, M.J. (2008). Opportunities to enhance performance and efficiency through nutrient synchrony in forage-fed ruminants. *Journal of Animal Science* 86: E306-E317.

Holter, J.B., Urban Jr., W.E., Hays, H.H. and Davis, H.A. (1977). Utilization of diet components fed blended or separately to lactating cows. *Journal of Dairy Science* 60: 1288-1293.

Hooft, K., Milar, D., Geerlings, E. and Django, S. (2008). *Endogenous Livestock Development in Cameroon*. Agromisa Publishers, Wageningen, The Netherlands. Pp24.

Hristov, A.N. and Pfeffer, E. (2005). *Nitrogen and phosphorous nutrition of cattle*. CABI Publishing. USA. Pp118.

Huhtanen, P. (1988). The effects barley, unmolassed beet pulp and molasses supplements on organic matter, nitrogen and fibre digestion in the rumen of cattle given a silage diet. *Animal Feed Science and Technology* 20: 259-278.

Huijsman, A. (1987). Prospects of intensive goat rearing in the humid zone of Nigeria. *WADG (West African Dwarf Goat) Project Report*. Royal Tropical Institute, Amsterdam, The Netherlands.

Humphreys, L.R. (1991). *Tropical Pasture Utilization*. Cambridge University Press, Cambridge, UK, 206pp.

Illius, A.W. and Gordon, I.J. (1991). Prediction of intake and digestion in ruminants by a model of rumen kinetics integrating animal size and plant characteristics. *Journal of Agricultural Science* 116: 145-157.

ILRI (International Livestock Research Institute). (1995). In: Gardiner, P. and Devendra, C. (Eds.), *Global agenda for livestock research Proceeding Consultation*, Nairobi, Kenya, 114pp.

Ishler, V., Heinrichs, J. And Varga, G. (1996). From feed to milk: Understanding Rumen Function. Extension Circular 422. The Pennsylvania State University. 27pp.

Johson, D.D. and McGowan, C.H. (1998). Diet/management effects on carcass attributes and meat quality of young goats. *Small Ruminant Research* 28(1): 93-98.

Johson, P.L., Purchas, R.W., Mcewan, J.C. and Blair, H.T. (2005). Carcass composition and meat quality differences between pasture-reared ewes and ram lambs. *Meat Science* 71(2):383-391.

Jordaan, J.D. (2004). The influence of bedding material and collecting period on the feeding value of broiler and layer litter. M.Sc. Thesis, University of Free State, South Africa.

Kabir, F. and Pazdeh, P. (2002). *Handbook of normal values in domestic animals*. Nourbakhsh Press, pp 58-59.

Kagira, J. and Kanyari, P.W.N. (2001). The role of parasitic diseases as causes of mortality in small ruminants in high-potential farming area in central Kenya. *Journal of the South African Veterinary Association* 72(3): 147-149.

Kallah, M.S. (2004). Rangeland in Nigeria: A partial resource appraisal. In: Gefu, J.O. and Amodu, J.T. (eds). 2004. *Forage production and management in Nigeria, a training manual*. National Animal Production Research Institute, Ahmadu Bello University, Zaria, Nigeria, October 2004. Pp 1-10.

Kallah, M.S. (2004). Rangelands in Nigeria: A partial resource appraisal towards improving livestock production. In: Gefu, J.O. and Amodu, J.T. (Eds.), *Forage Production and Management in Nigeria*. National Animal Production Research Institute. Ahmadu Bello University, Zaria, Nigeria, pp. 1-10.

Kamra, D.N. (2005). Rumen microbial ecosystem. *Current Science* 89 (1): 124-135.

Kaneko, J.J. (1989). *Clinical Biochemistry of Domestic Animals.* 5th Edn. Academic Press Inc., New York, USA. Pp 44-85.

Kanjanapruthipong, J. and Leng, R.A. (1998). The effects of dietary urea on microbial populations in the rumen of sheep. *Asian-Australian Journal of Animal Science* 11: 661-672.

Kargar, S., Khorvash, M., Ghorbani, G.R., Alikhani, M. and Yang, W.Z. (2010). Short communication: effects of dietary fat supplements and forage: concentrate ratio on feed intake, feeding and chewing behavior of Holstein dairy cows. *Journal of Dairy Science* 93: 4297-4301.

Kaswari, T., Lebzien, P. and Flachowsky, G. (2007). Studies on the relationship between the synchronization index and the microbial protein synthesis in the rumen of dairy cows. *Animal Feed Science and Technology* 139:1-22.

Khaki, Z., Atyabi, N., Abasalipour, K.M. and Khazraeenia, P. (2005). *Clinical biochemistry of domestic animals* (In farsi). University of Tehran Press.

Khampa, S. and Wanapat, M. (2007). Manipulation of rumen fermentation with organic acids supplementation in ruminants raised in the tropics. *Pakistan Journal of Nutrition* 6: 20-27.

Khorasani, G.R., Deboer, G., Robinson, B. and Kennelly, J.J. (1994). Influence of dietary protein and starch on production and metabolic responses of dairy cows. *Journal of Dairy Science* 77: 813-824.

Kim, K.H., Chloung, J.J. and Chamberlian, D.G. (1999). Effects of varying the degree of synchrony of energy and nitrogen release in the rumen on the synthesis of microbial protein in lactating dairy cows consuming diet of grass silage and a cereal-based concentrate. *Journal of Agricultural Science* 79: 1441-1447.

Kolver, E., Muller, L.D., Varga, G.A and Cassidy, T.W. (1998). Synchronization of ruminal degradation of supplemental carbohydrates with pasture nitrogen in lactating dairy cows. *Journal of Dairy Science* 81: 2017-2028.

Kosum, N., Alcicek, A., Taskin, T. and Onenc, A. (2003). Fattening performance and carcass characteristics of Saanen and Bornova male kids under an intensive management system. *Czech Journal of Animal Science* 48(9): 379-386.

Krause, K.M. and Oetzel, G.R. (2006). Understanding and preventing subacute ruminal acidosis in dairy herds. A review. *Animal Feed Science Technology* 126: 215-236.

Kung, L.J. (2011). The role of fibre in Ruminant Ration Formulation. Retrieved April 20, 2014, from http//:marjuki-lecture.ub.ac.id/files/2013.

Lakpini, C.A.M. (2002). Management of sheep and goats. In: Lakpini, C.A.M., Adamu, A.M., Ehoche, O.W. and Gefu, J.O. (Eds), *Manual for Small Ruminant Production in Nigeria*. Compilation for a training workshop on small ruminant production held at the National Animal Production Research Institute, Ahmadu Bello University, Zaria, Nigeria, 13th to 18th January, 2002. Pp 12-16.

Lawal-Adebowale, O.A. (2012). Dynamics of ruminant livestock management in the context of the Nigerian Agricultural System. Retrieved April 20 from http://dx.doi.org/10.5772/52923.

Lazzarini, I. (2007). Consumo, Digestibilidade e dinâmicas de trânsito e degradaçâo da fibra em detergente neutro em bovinos alimentados com forragem tropical de baixa qualidade e compostos nitrogenados. Departamento de Zootecnia/Universidade Federal de Viçosa, Viçosa (M.S. Thesis).

Lebbie, S.H.B. (2004). Goats under Household Conditions. *Small Ruminant Research* 51: 131-136.

Leng, R.A. (1982). Modification of rumen fermentation. In: Hacker, J.B. (Ed.), *Nutrition limits to animal production from pastures*. CAB, Farnham Royal, England, pp: 427-453.

Leonard, S. (1957). *Continuous Flow Analysis*. Retrieved April 20, 2014, from http://www.labmate-online.co.

Lintzenich, B.A., Vanzant, E.S., Cochran, R.C., Beaty, J.L., Brandt, Jr. and St. Jean, G. (1995). Influence of processing supplemental alfalfa on intake and digestion of dormant bluestem-range forage by steers. *Journal of Animal Science* 73: 1187-1195.

Liu, X., Wang, Z. and Lee, F. (2005). Influence of concentrate level on dry matter intake, N balance, nutrient digestibility, ruminal flow rate, and nutrient degradability in sheep. *Small Ruminant Research* 58(1): 56-62.

Lowman, B.G. and Lewis, M.L. (1991). The feeding and management of intensively reared bulls: conventional compared with organic. In: Haresign, W. and Cole, D.J.A. (Eds), *Recent Advances in Animal Nutrition*. Butterworth-Heinemann Ltd, Oxford, pp. 181-209.

Lufadeju, E.A. (1988). Evaluation of methods of improving utilization of mature *Ropozon gayanus* (Gamba Hay) by Friesian Bunaji heifers. Ph.D. Thesis. Ahmadu Bello University, Zaria, Nigeria.

Luginbuhl, J. (2000). *Meat Goat Production in North Carolina*. Retrieved May 6, 2011, from www.cals.nscu.edu/an-sci/extension/animal/meatgoat/mgpoduction.html.

Lusby, K.S. and Wagner, D.G. (1986). Effects of supplements on feed intake. In: Owens, F.N. (Ed.) *Symposium Proceeding: Feed intake by Beef Cattle*. Pp 173-181. Oklahoma Agricultural Experimentation Station, MP-121.

Macmillan Nigeria. (2006). *Secondary Atlas*. Dada, F.O.A, Jibrin, G.M. and Iyeoma, A. (Eds). Lagos-Ibadan. Nigeria. Macmillan. 136pp.

Madibela, O.R. and Segwagwe, B.V.E. (2008). Nutritional effects of supplementary feeding on maternal blood metabolites, cortisol, thyroid hormones levels and on outcome of pregnancy of dry season kidding Tswana goats. *Livestock Research and Rural Development* 20(4).

Mamani-Linares, L.W. and Gallo, C. (2013). Effects of supplementary feeding on carcass and meat quality traits of young llamas (*Lama glama*). *Small Ruminant Research* 114: 233-239.

Mandebvu, P. and Galbraith, H. (1999). Effect of sodium bicarbonate supplementation and variation in the proportion of barley and sugar beet pulp on growth performance and rumen, blood characteristics in young entire lambs. *Animal Feed Science and Technology* 82:37-49.

Manninen, M., Jauhiainen, L., Ruusunen, M., Soveri, T., Koho, N. and Pösö, R. (2010). Effects of concentrate type and level on the performance and health of finishing Hereford bulls given a grass Silage-based diet and reared in cold conditions. *Livestock Science* 127: 227-237.

Manoji, K. G., and Samiran, B. (2007). Mimosine toxicity-A problem of *Leucaena* feeding in Ruminants. *Asian Journal of Animal and Veterinary Advances* 2: 63-73.

Markham, R. (1942). A steam distillation apparatus suitable for micro Kjeldahl analysis. *Journal of Biochemistry* 36: 790-791.

Martin, C., Morgavi, D.P. and Doreau, D. (2010). Methane mitigation in ruminants: from microbe to the farm scale. *Animal* 4: 351-365.

Matejovsky, K.M. and Sanson, D.W. (1995). Intake and digestion of low-, medium-, and high-quality grass hays by lambs receiving increasing levels of corn supplementation. *Journal of Animal Science* 73: 2156.

Mathis, C.P., Cochran, R.C., Heldit, J.S., Woods, B.C., Abdelgadir, I.E.O., Olson , K.C., Titgemeyer, E.C. and Vanzant, E.S. (2000). Effects of supplemental degradable intake protein on utilization of medium to low- quality forages. *Journal of Animal Science* 78: 224-232.

McDonald, P., Edward, R.A., Greenhalgh, J.F. and Morgan, C.A. (1996). *Animal Nutrition*. Longman Scientific and Technical, Harlow, UK. 155pp.

McGuire, D.L., Bohnert, D.W., Schauer, C.S., Falck, S.J. and Cooke, R.F. (2013). Daily and alternate day supplementation of urea or soybean meal to ruminants consuming low-quality cool-season forage: I-Effects on efficiency of nitrogen use and nutrient digestion. *Livestock Science* 155: 205-213.

Mertens, D.R. (1997). Creating a system for meeting the fibre requirements of dairy cows. *Journal of Dairy Science* 80: 1463-1481.

Mertens, D.R. and Loften, J.R. (1980). The effects of starch on forage fibre digestion kinetics in vitro. *Journal of Dairy Science* 63: 1437.

Meyer, D.J. and Harwey, J.W. (2004). *Veterinary Laboratory Medicine: Interpretation and diagnosis*. 3rd Ed. Sounders, W.B., Philadelphia, pp 311-312.

Milo, D. (2010). *Nutritional values of cottonseed cake*. Retrieved February 22, 2013, from www.Livestrong.com.

Mohgoub, O. and Lu, C.D. (2004). Influence of various levels of metabolisable energy on chemical composition of whole carcass and non-carcass portion of goats and sheep. *South African Journal of Animal Science* 34 (1): 81-84.

Mojabi, A. (2000). *Veterinary Clinical Biochemistry* (In farsi). 2nd Ed. Nourbakhsh Press, pp 421-429.

Moore, J.E., Brant, M.H., Kunkle, W.E. and Hopkins, D.I. (1999). Effects of supplementation on voluntary forage intake, diet digestibility, and animal performance. *Journal of Animal Science* 77: 122-135.

Morita, S. and Nishino, S. (1991). Effects of arrangement of feeding order of diets on probability of eating bout continuing and frequency of eating bout in steers. *Japanese Journal of Livestock Management* 26: 75-81.

Morita, S. and Nishino, S. (1993). Effect of mixing diets and sequence of feeding on the amount of intake, time spent eating and changes of eating behaviour with time after feeding in steers. *Journal of RakunoGakuen University* 18(1/2): 13-20.

Mould, F.L., Ørskov, E.R. and Mann, S.O. (1983). Associative effects of mixed feeds. In: Effects of type and level of supplementation and the influence of the rumen fluid pH on cellulolysis *in vivo* and dry matter digestion of various roughages. *Animal Feed Science and Technology* 10:15-30.

Mtenga, L.A. and Kitalyi, A.J. (1990). Performance and carcass composition of Tanzania goats fed *Chloris gayana* hay with supplements containing different levels of protein. *Small Ruminant Research* 3(1): 1-8.

Mulliniks, J.T., Mathis, C.P., Cox, S.H. and Petersen, M.K. (2013). Supplementation strategy during late gestation alters steer progeny health in the feedlot without affecting cow performance. *Animal Feed Science and Technology* 185: 126-132.

Mulliniks, J.T., Sawyer, J.E., Mathis, C.P., Cox, S.H. and Petersen, M.K. (2012). Winter protein management during late gestation alters range cow and steer progeny performance. *Journal of Animal Science* 90: 5099-5106.

Newbold, J.R. and Rust, S.R. (1992). Effect of asynchronous nitrogen and energy supply on growth of ruminal bacteria in batch culture. *Journal of Animal Science* 70: 538-546.

Njidda, A.A. (2010). Chemical composition, fibre fraction and anti-nutritional substances of semi-arid browse forages of North-Eastern Nigeria. *Nigerian Journal of Basic and Applied Science* 18(2): 181-188.

Nocek, J.E. (1992). Feeding sequence and strategy effects on rumen environment and production performance of first lactation cows. *Journal of Dairy Science* 75: 3100-3108.

Nocek, J.E. (1997). Bovine acidosis: implications on laminitis. *Journal of Dairy Science* 80: 1005-1028.

Nocek, J.E., Steele, R.L. and Braud, D.G. (1986). Performance of dairy cows fed forage and grain separately versus a total mixed ration. *Journal of Dairy Science* 69: 2140-2147.

Nordlund, K.V., Garrett, E.F. and Oetzel, G.R. (1995). *Herd-based rumenocentesis: a clinical approach to the diagnosis of sub-acute rumen acidosis*. The Compendium X. pp. 48-56.

Norton, B.W. (1994). Tree legumes as dietary supplements for ruminants. In: Gutteridge, R.C. and Shelton, H.M. (Eds.). *Forage tree legumes in tropical Agriculture*. (CAB International), pp 192-201.

NRC (National Research Council). (2000). *Nutrient requirements of beef cattle*, 7th edition, National Academies Press, Washington, DC. Retrieved April 12, 2013, from http://www.nap.edu/catalog.php?record-id=9791.

Nuru, S. (1985). Trends in small ruminant production in Nigeria. *Proceedings of the National Conference on Small Ruminant Production*, Zaria, Nigeria, pp: 35-48.

Oba, M. and Allen, M.S. (1999). Evaluation of the importance of digestibility of neutral detergent fibre from forage: Effects on dry matter intake and milk yield of dairy cows. *Journal of Dairy Science* 82: 589-596.

Okorie, A.U. and Sanda, L.U. (1992). Rangeland and grazing reserve. In: *Nigeria: Livestock sub-sector review*. Food and Agricultural Organization (FAO) 2: 2-15.

Okpebholo, F. and Kahan, T. (2007). Opportunities and Challenges for Developing Small Ruminant Systems. Official Newsletter of the Florida Meat Goat Association, *The Caprine Chronicle* 22: 4.

Olateru, F. and Adegbola, T.A. (2001). Effect of source and level of nitrogen on the utilization of sorghum stover by Yankasa rams. *Nigerian Journal of Animal Production* 28: 187-192.

Olson, K.C., Cochran, R.C., Jones, T.J., Vanzant, E.S., Titgemeyer, E.C. and Johnson, D.E. (1999). Effects of ruminal administration of supplemental degradable intake protein and starch on utilization of low-quality warm-season grass hay by beef steers. *Journal of Animal Science* 77: 1016-1025.

Oludimu, O.L. (1992). Management of the West African dwarf goat in the humid tropics: A socio-economic appraisal of feeding regimes. Retrieved November 8, 2013, from http://www.fao.org/../x5519b1i.htm

Omoike, A. (2006). Nigeria. *Journal of Agriculture and Social Research* 6 (2): 23-31.

Onwuka, C.F.I., Adetiloye, P.O. and Afolami, C.A. (1997). Use of Household wastes and crop residues in small ruminant feeding in Nigeria. *Small Ruminant Research* 24: 233-237.

Onwuka, C.F.I., Akinsoyinu, A.O. and Tewe, O.O. (1989). Feed value of some Nigerian Browse species: Chemical composition and in Vitro digestibility of leaves. *East African Journal of Agriculture* 54: 157-163.

Ørskov, E.R. (1982). *Protein Nutrition in Ruminants.* Academic Press Inc., London. 155pp.

Ørskov, E.R. (1991). Manipulation of fibre digestion in the rumen. In: *Proceedings of Nutritional Society*, 50(2): 187-196.

Ørskov, E.R. and Fraser, C. (1975). The effects of processing of barley-based supplements on rumen pH, rate of digestion and voluntary intake of dried grass in sheep. *British Journal of Nutrition* 34: 393.

Osinowo O.A., Abubakar B.Y., Adewuyi A.A., Onifade O.S. and Dennar P.O. (1991). Estimates of genetic and phenotypic parameters of birth weight, weaning weight and pre-weaning gain in Yankasa sheep. Pp. 205-215 in Proc. 16th Annual Conference of the Nigerian Society for Animal Production, Usman Danfodio University, Sokoto, Nigeria.

Osinowo, O.A., Abubakar, B.Y., Olayemi, M.E., Balogun, R.A., Onifade, O.S., Adewuyi, A.A., Trimnell, A.R. and Dennar, F.O. (1992). Pre-weaning performance of Yankasa sheep under semi-intensive management. Retrieved November 14, 2014, from http://www.fao.org/wairdocs/ilri/.../x5472b0e.

Osuhor, C.U. (2002). Techniques for Fattening Rams and Bucks In: Lakpini, C.A.M., Adamu, A.M., Ehoche, O.W. and Gefu, J.O. (Eds), *Manual for Small Ruminant Production in Nigeria*. Compilation for a training workshop on small ruminant production held at the National Animal Production Research Institute, Ahmadu Bello University, Zaria, Nigeria. 13th to 18th January, 2002. Pp 63-67.

Otaru, S.M. (1998). Growth performance of red Sokoto bucks fed varying proportions of Fig (*Ficus thoningii*) leaves in a basal Gamba (*Andropogon gayanus*) grass diets. M.Sc. Thesis, Department of Animal Science, Ahmadu Bello University, Zaria, Nigeria.

Otaru, S.M. (2009). Effect of palm oil supplementation on lactation performance of Red Sokoto goats. Ph.D. thesis, Department of Animal Science, Ahmadu Bello University, Zaria. Pp69.

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

Otaru, S.M., Adamu, A.M., Ehoche, O.W. and Makun, H.J., (2013). Effects of varying levels of dietary in concentrate rations on dry matter intake, nutrients digestibility and nitrogen retention in Red Sokoto goats. *Nigerian Journal of Animal Science* 40: 122-133.

Ovimaps (2012). Ovilocation map: Oviearth imagery data.

Ozung, P.O., Nsa, E.E., Ebegbulem, V.N. and Ubua, J.A. (2011). The potentials of small ruminant production in Cross River Rain Forest zone of Nigeria: A review. *Continental Journal of Animal and Veterinary Research* 3(1): 33-37.

Paterson, R.T., Kiruiro, E. and Arimi, H.K. (1999). *Calliandra colothyrsus* as a supplement for milk production in the Kenya Highland. *Tropical Animal Health and Production* 31: 115-126.

Patra, A.K. (2009). A meta-analysis on effects of supplementing low-quality roughages with foliages from browses and tree fodders on intake and growth in sheep. *Livestock Science* 121: 239-249.

Patra, A.K. (2012). Enteric methane mitigation technologies for ruminant livestock: a synthesis of current research and future directions. *Environment Monitoring and Assessment* 184: 1929-1952.

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: 244-254.

Paulino, M.F., Detmann, E., Valadares Filho, S.C. (2006). Supplementação animal em pasto: energética ou protéica? *Proceedings of 3rd Symposium on Strategic Management of Pasture*, Viçosa, Brazil, pp. 359-392.

Peters, A., Lebzien, P., Meyer, U.,Bochert, U., Bulang, M. and Flachowsky, G. (2010). Effect of exogenous fibrolytic enzymes on ruminal fermentation and nutrient digestion in dairy cows. *Archive of Animal Nutrition* 64: 221-237.

Pezo, O., Benarides, J., Romero, F. and Chaves, C. (1990). Potential of legume tree fodder as animal feed in Central America. In: Devendra, C. (Ed.) *Shrubs and Tree Fodders for Farm Animals*. IDRC, Ottawa, Ontario Canada, Pp 163-175.

Plaizier, J.C., Krause, D.O., Gozho, G.N. and McBride, B.W. (2008). Subacute ruminal acidosis in dairy cows: the physiological causes, incidence and consequences. *Veterinary Journal* 176: 21-31.

Pordomingo, A.J., Wallace, J.D., Freeman, A.S. and Galyean, M.L. (1991). Supplemental corn grain for steers grazing native rangeland during summer. *Journal of Animal Science* 69: 1678.

Preston, T.R. and Leng, R.A. (1987). *Matching ruminant production systems with available resources in the Tropics and Sub-tropics*. Penambul Books Ltd: Armidale. NSW, Australia. Pp245.

Raeth-Knight, M.L., Linn, J.G. and Jung, H.G. (2007). Effect of direct-fed microbial on performance, diet digestibility, and rumen characteristics of Holstein dairy cows. *Journal of Dairy Science* 90: 1802-1809.

Ramesh, C.S. (2000). *Neem for sustainable development and environmental conservation: Indian Perspective,* pp.39-51. Retrieved February 11, 2014, from http://www.neemfoundation.org/neem-articles/neem-sustainable.html.

Reed, J.J., Gelvin, A.L., Lardy, G.P., Bauer, M.L. and Caton, J.S. (2006). Effect of creep feed supplementation and season on intake, microbial protein synthesis and efficiency, ruminal fermentation, digestion, and performance in nursing calves grazing native range in southeastern North Dakota. *Journal of Animal Science* 84: 411-423.

Rege, J.E.O. (1994). *Indigenous African small ruminants: a case for characterization and improvement*. Retrieved October 18, 2014, from www.fao.org/wairdocs/ilri.../x5472b14.

Richardson, J.M., Wilkin, R.G. and Siclair, L.K. (2003). Synchrony of nutrient supply to the rumen and dietary energy source and their effect on the growth and metabolism of lambs. *Journal of Animal Science* 81: 1332-1347.

Richardson, J.M., Wilkison, R.G. and Sinclair, L.A. (2003). Synchrony of nutrient supply to the rumen and dietary energy source and their effects on the growth and metabolism of lambs. *Journal of Animal Science* 81: 1332-1347.

Robinson, P.H. (1994). Strategies of feeding high-energy supplement to primiparous dairy cows. *Canadian Journal of Animal Science* 74: 487-493.

Robinson, P.H., Gill, M. and Kennelly, J.J. (1992). Influence of feeding sequence on ruminal fermentation and duodenal flow. *Canadian Journal of Animal Science* 72: 1007 (Abstract).

Robison, P.H. (1989). Dynamic aspects of feeding management for dairy cows. *Journal of Dairy Science* 75: 3100-3108.

Russell, J.B. and Hespell, R.B. (1981). Microbial rumen fermentation. *Journal of Dairy Science* 64: 1153-1169.

Russell, J.B., O'onnor, J.D., Fox, D.G., Van Soest, P.J. and Sniffen, C.J. (1992). A net carbohydrate and protein system for evaluating cattle diets: I. Ruminal fermentation. *Journal of Animal Science* 70: 3551-3561.

Salem, A.Z.M., Zhou, C., Tan, Z., Mellado, M. Salazar, M.C., Elghndopour, M.M.M.Y. and Odongo, N.E. (2013). *In vitro* ruminal gas production kinetics of four fodder trees ensiled with or without molasses and urea. *Journal of Integrative Agriculture* 12(7): 1234-1242.

Sampaio, C.B. (2007). Consumo, digestibilidade e dinâmica ruminal em bovinos alimentados com forragem tropical de baixa qualidade supplementados com compostos nitrogenados. Departmento de Zootecnia / Universidade Federal de Viçosa, Viçosa (M.S. Thesis).

Sanson, D.W., Clanton, D.C. and Rush, I.G. (1990). Intake and digestion of low-quality meadow hay by steers and performance of cows on native range when fed protein supplements containing various levels of corn. *Journal of Animal Science* 68: 595.

Sarwar, M., Khan, M.A. and Iqbal, Z. (2002). Feed resources for livestock in Pakistan. *International Journal of Agriculture and Biology* 4: 186-192.

SAS Institute, Inc. (2002). *SAS user's guide: Statistics*. Version 9. SAS Institute, Carry, NC 27513, USA.

Sastradipradja, D. (1998). Glucose in Ruminants. A Review. *Ulas Balik* 5, pp 59-65.

Satter, L.D. and Slyter, L.L. (1974). Effect of ammonia concentration on rumen microbial protein production *in Vitro*. *British Journal of Nutrition* 32: 199-208.

Sawyer, J.E., Mulliniks, J.T., Waterman, R.C. and Petersen, M.K. (2012). Influence of protein type and level on nitrogen and forage utilization in cows consuming low-quality forage. *Journal of Animal Science* 90: 2324-2330.

Schilcher, B., Baumgartner, K., Geyer, H. and Liesegang, A. (2013). Investigations on rumen health of different wild ruminants in relation to feeding management. *Journal of Zoo and Aquarium Research* 1(1): 28-30.

Severud, W.J., Windels, S.K., Belant, J.L. and Bruggink, J.G. (2013). The role of forage availability on diet choice and body condition in American beavers (*Castor canadensis*). *Mammalian Biology* 78: 87-93.

Seyoum, S. (1992). Economics of small ruminant meat production and consumption in Sub-Saharan Africa. Small Ruminant Research and Development in Africa, *Proceedings of the First Biennial Conference of the African Small Ruminant Research Network*, ILRAD, Nairobi, 10-14 December 1990. Nairobi, Kenya, pp: 25-46.

Sharma, R.K., Singh, B. and Sahoo, A. (2008). Exploring feeding value of oak (*Querus incana*) leaves: Nutrient intake and utilization in calves. *Livestock Science* 118: 157-165.

Shiawoya, E.L. (2006). Practical manual on some major forage and fodder crops in the Guinea Savanna zone of Nigeria. Department of Animal Production, Federal University of Technology, Minna, Nigeria. Pp. 1-37.

Shiawoya, E.L. and Tsado, D.N. (2011). Forage and fodder crop production in Nigeria: Problems and Prospects. *World Journal of Life Science and Medical Research* 1(4): 88-93.

Sibanda, S. and Said, A.N. (1993). The role of crop- residues and agro-industrial by-products as animal feed resources in sub-Saharan Africa. In: Adamu, A.M., Mani, R.I., Osinowo, O.A., Adeoye, K.B. and Ajileye, E.O. (Eds.). *Forage Production and Utilization in Nigeria*: *Second Livestock Development Project*. Proceedings of a Workshop on Forage Production and Utilization in Nigeria held in Zaria, Nigeria, 11-14 February, 1991. NLPD (National Livestock Projects Division), Federal Ministry of Agriculture and Water Resources, Kaduna, pp. 186-112.

Sinclair, L.A., Garnsworthy, P.C., Newbold, J.R. and Buttery, P.J. (1993). Effect of synchronizing the rate of dietary energy and nitrogen release on rumen fermentation and microbial protein synthesis in sheep. *Journal of Agricultural Science* (Camb.) 120: 251-263.

Singh, B.B., Musa, A., Ajeigbe, H.A. and Tarawali, S.A. (2011). Effect of feeding crop residues of different cereals and legumes on weight gain of Yankasa rams. *International Journal of Livestock Production* 2: 017-023.

Smith, O.B. (1992). Small ruminant feeding systems for small scale farmers in humid West Africa. In: Stares, J.E.S., Said, A.N. and Kategile, J.A. (eds). 1992. *The complementarity of feed resources for animal production in Africa*. Proceedings of the joint feed resources networks workshop held in Gaborone, Botswana, 4-8 Mach 1991. African Feeds Research Network. ILCA (International Livestock Centre for Africa), Addis Ababa. Ethiopia. Pp 363-376.

Smith, O.B. (1993). Feed resources for intensive small holder systems in the tropics: The role of crop residues. In: Baker, M.J., Crush, J.R. and Humphreys, L.R. (Eds.), *Proceedings of the 17th International Grassland Congress*; *Australia/New Zealand*, 8-21 February, 1993. 111: 1969-1976.

Souza, M.A. (2007). Consumo, digestibilidade e dinâmica ruminal em bovinos alimentados com forragem tropical de baixa qualidade supplementados com compostos nitrogenados e/ou carboidratos. Departmento de Zootecnia / Universidade Federal de Viçosa, Viçosa (M.S. Thesis).

Steger, H., Voigt, J. and Piatkowski, B. (1970). Einfluss der Futterration und des Entnahmezeitpunktes von Pansensaft uf seine Zusammensetzung in Untersuchungen an Kühen. *Archive. Tierernährung* 20: 349-359.

Stockdale, C.R. (2008). Effects of body condition score at calving and feeding various types of concentrate supplements to grazing dairy cows on early lactation performance. *Livestock Science* 116: 191-202.

Suberu, M.Y., Bashir, N. and Mustafa, M.W. (2013). Biogenic waste methane emissions and methane optimization for bioelectricity in Nigeria. *Renewable and Sustainable Energy Reviews* 23: 643-654.

Tafaj, M., Zebeli, Q., Baes, Ch., Steingass, H. and Drochner, W. (2007). A meta-analysis examining effects of particle size of total mixed rations on intake, rumen digestion and milk production in high-yielding dairy cows in early lactation. *Animal Feed Science and Technology* 138: 137-161.

Tellier, R.C., Mathison, G.W., Okine, E.K., McCartney, D. and Soofi-Siawash, R. (2004). Frequency of concentrate supplementation for cattle fed barley straw. 2. Ruminal dilution rates, pH and metabolite concentrations. *Canadian Journal of Animal Science* 84: 467-479.

Therrien, J.F., Coté, S.C., Festa-Bianchet, M. and Ouellet, J.P. (2008). Maternal care in white-tailed deer: trade-off between maintenance and reproduction under food restriction. *Animal Behaviour* 75: 235-243.

Totanji, A.L. and Lubbadeh, W. (2000). Effect of feeding different levels of energy and protein during the last two months of gestation on Shami goats' performance in Jordan Valley. *Dirasat Agricultural Science* 27(2): 165-175.

Traxler, M.J., Fox, D.G., Van Soest, P.J., Pell, A.N., Lascano, C.E., Lanna, D.P.D., Moore, J.E., Lana, R.P., Vélez, M. and Flores, A. (1998). Predicting forage indigestible NDF from lignin concentration. *Journal of Animal Science* 76: 1469-1480.

Trevaskis, L.M., Fukerson, W.J. and Gooden, J.M. (2001). Provision of certain carbohydrate based supplements to pasture fed sheep as well as time of harvesting of the pasture influences pH, ammonia concentration and microbial protein synthesis in the rumen. *Australian Journal of Experimental Agriculture* 41: 21-27.

Tufarelli, V., Khan, R.U. and Laudadio, V. (2011). Feeding of wheat middling in lamb total mixed ration: Effects on growth performance and carcass traits. *Animal Feed Science and Technology* 170: 130-135.

Ugwu, D.S. (2007). The role of small ruminants in the household economy of Southeast zone of Nigeria. *Research Journal of Applied Sciences* 2(6): 726-732.

Ukpabi, U.H. and Abdu, L.S. (2009). Effect of mucuna seed meal on dry matter intake and haematology of lactating African dwarf goats. *Proceedings of the 34th Annual Conference of Nigerian Society for Animal Production*, March 15-18, 2009. Uyo, Nigeria, pp: 562-564.

Umeh, L.I. (2004). Nigeria: Food Security and Agriculture Development, Horizon 2015: Summary National Strategy prepared for FAO.

Uyeno, Y., Sekiguchi, Y., Tajima, K., Takenaka, A., Kurihara, M. and Kamagata, Y. (2010). An rRNA-based analysis for evaluating the effect of heat stress on the rumen microbial composition of Holstein heifers. *Anaerobe* 16: 27-33.

Van Soest, P.J. (1994). *Nutritional Ecology of the Ruminant*, 2nd ed., Cornell University Press, USA. Pp 476.

Van Soest, P.J., Mascarenhas-Ferreira, A. and Hartley, R.D. (1991). Chemical properties of fibre in relation to nutritive quality of ammonia treated forages. *Animal Feed Science and Technology* 10:155.

Voight, J., Piatkowski, B. and Krawielitzki, R. (1978). The effect of order of roughage and concentrates in feeding on carbohydrate digestion and bacterial protein synthesis in the rumen of the dairy cow. *Archive Tierernahr* 28: 67-76.

Wanapat, M., Puramangkan, T. and Siphuak, W. (2000). Feeding Cassava hay to lactating dairy cows. *Asian Austrian Journal of Animal Science* 13(4): 478-482.

Wang, M., Wang, H., Cao, H., Li, G. and Zhang J. (2008). Effects of limiting amino acids on rumen fermentation and microbial community *In Vitro*. *Agricultural Sciences in China* 7(12): 1524-1531.

Warmington, B.G. and Kirton, A.H. (1990). Genetic and Non-genetic Influences on Growth and Carcass Traits of Goats. *Small Ruminant Research* 3(2): 147-165.

Weaver, S. (2005). Sheep: Small Scale Sheep Keeping for Pleasure and Profit. Burroughs Irvine, Hobby Farm Press. Pp. 121-234.

Wiley, J.S., Petersen, M.K., Ansotegui, R.P. and Bellows, R.A. (1991). Production from first-calf beef heifers fed a maintenance or low level of prepartum nutrition and ruminally undegradable or degradable protein postpartum. *Journal of Animal Science* 69: 4279-4293.

Williams, C.E and Williams, S.K.T. (1991). Extension services in livestock production sector in Nigeria. *Nigerian Journal of Rural Extension and Development* 1: 1-13.

Winrock International (1992). *Assessment of Animal Agriculture in Sub-Saharan Africa*. Winrock International Institute for Agricultural Development, Morrilton, Arkansas, USA. Pp. 59.

Witt, M.W., Sinclair, L.A., Wikinson, R.G. and Buttery, P.J. (1997). Effect of synchronizing the rate of energy and nitrogen supply to the rumen in diets with two rate of carbohydrate release on growth and metabolism of male lambs. In: *proceedings of British Society of Animal Science, Annual Meeting March 1997*. British Society of Animal Science, 2.

Yang, J.Y., Seo, J., Kim, H.J., Seo, S. and Ha, J.K. (2010). Nutrient Synchrony: Is it a suitable strategy to improve nitrogen utilization and animal performance? *Asian-Australian Journal of Animal Science* 7: 972-979.

Yang, W.Z. and Beauchemin, K.A. (2006). Physically effective fibre: method of determination and effects on chewing, ruminal acidosis, and digestion by dairy cows. *Journal of Dairy Science* 89: 2618-2633.

Zebeli, Q., Mansman, D., Steingass, H. and Ametaj, B.N. (2010). Balancing diets for physically effective fibre and ruminally degradable starch: A key to lower the risk of sub-acute rumen acidosis and improve productivity of dairy cattle. *Livestock Science* 127: 1-10.

Zervas, G. and Tsiplakou, E. (2011). The effect of feeding systems on the characteristics of products from small ruminants. *Small Ruminant Research* 101: 140-149.

Zervas, G., Zarkadas, L., Koutsotolis, K., Goulas, C. and Mantzios, A. (1999). The effect of altering the hay to concentrate ratio and concentrate composition on the rumen fermentation of dry sheep and milk production of lactating dairy ewes. *Animal Production* 69: 637-645.

Zeyner, A., GeiBler, C. and Dittrich, A. (2004). Effects of hay intake and feeding sequence on variables in faeces and faecal water (dry matter, pH value, organic acids, ammonia, buffering capacity) of horses. *Journal of Animal Physiology and Animal Nutrition* 88: 7-19.

Zhao, X., Liu, C., Li, C. and Yao, J. (2013). Effects of neutral detergent fibre and sucrose supplementation on ruminal fermentation, microbial synthesis, and population of ruminal cellulolytic bacteria using the rumen simulation technique (RUSITEC). *Journal of Integrative Agriculture* 12(8): 1471-1480.

Zvonko, S., Natalija, F., Pero, B., Zvonimir, T. and Josip, D. (2008). The metabolic profile of Simmental service bulls. *Veterinarski Arhiv* 78 (2): 123-129.