EFFECT OF SUPPLEMENTING RICE STRAW WITH PIGEON PEA FORAGE ON PERFORMANCE OF YANKASA SHEEP

BY

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SEPTEMBER, 2006

DECLARATION

This is to certify that this thesis has been written by me. It is a product of research work executed by me. It has not been accepted in any previous application for higher degree. All quotations are indicated and the sources of information arc specifically acknowledged by means of references.

_____ _____

G.E. Jokthan DATE

DEDICATION

This thesis is dedicated to the memory of my father: Mr. Husaini Idris who had been my inspiration and also to my children, Jonathan, Hannatu, Priscilla, Joel and Daniel.

CERTIFICATION

This thesis entitled “Effect of Supplementing Rice Straw with Pigeon Pea Forage on Performance of Yankasa Sheep” by Grace E. Jokthan meets the regulation governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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LIST OF ABREVIA TIONS

ADF	Acid Detergent Fibre
Cal	Calcium
Cell	Cellulose
CF	Crude Fibre
CP	Crude Protein
DM	Dry Matter
EE	Ether Extract
Fe	Iron
Hemi	Hemicellulose
K	Potassium
Lig	Lignin
Mg	Magnesium
MM	Milimol
Na	Sodium
NDF	Neutral Detergent Fibre
NFE	Nitrogen Fibre Extract
NlirN	Ammonia Nitrogen
OM	Organic Matter
P	Phosphorus
PF	Pigeon pea forage

PUN Plasma Urea Nitrogen

S Sulphur

SCFA Short chain fatty acid

VFA Vo1alile fatty acid

SI Silica

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ABSTRACT

A study were conducted to evaluate the feeding value of rice straw supplemented with varying levels of pigeon pea forage as dry season feed for yearling Yankasa ewes.

In trial I, twenty yearling ewes with body weight ranging between 14.98 and 15.06kg were randomly assigned to four treatments. Five ewes per treatment comprising a basal rice straw diet fed *ad libitum* (0.0% pigeon pea forage), and *ad libitum* rice straw supplemented with pigon pea forage at 0.5, 1.0 and 1.5% of body weight. The proximate and mineral composition of the feed ingredients showed that rice straw had 10.81% CP, 5.11% lignin and 4.27% silica while pigeon pea forage had 15.75% CP, 3.63% lignin and 0.5mg/kg tannin. In terms of mineral contents analysed, pigeon pea forage was higher than rice straw only in calcium. The result of the feeding trial showed increased feed intake with increase in level of pigeon pea forage supplementation. Ewes on the unsupplemented and 0.5% body weight supplementation lost weight (-2.01kg and -1.6kg respectively) while those on 1.0 and 1.5% supplementation had minimal (1.25kg and 1.06kg respectively) weight gain. Their feed efficiencies were low (473.25 and 518.48 respectively).

The digestibility and nitrogen balance trial showed significant differences ($P<0.5$) in the digestion of DM, OM, NDF and ADF across the treatments. Supplementing rice straw based diet with 1.0% of body weight pigeon pea forage resulted in better digestibility of all nutrients. Nitrogen retention across all treatments was high and ranged between 86.19 and 90.06 percent.

Rumen and blood metabolite trial showed increase in the levels of plasma urea nitrogen, rumen ammonia and volatile fatty acids as a result of pigeon pea supplementation. The levels of these rumen metabolites were highest at 1.0% of body weight supplementation with maximum levels recorded between 6. 12 hours post – feeding. Mean rumen pH measured (6.63 – 6.87) remained within the range of normal pH expected in the rumen. Levels of calcium phosphorus, magnesium,

sodium and iron in the rumen fluid were within the recommended levels for maintenance of sheep in the tropics. Plasma urea nitrogen, packed cell volume, haemoglobin and white blood count were highest (4.94mm/L, 32.00% and 73.00% respectively) at 1.0% of body weight pigeon pea forage supplementation.

The dry matter (DM) degradation trial showed a linear increase in DM degradation as hours of incubation increased. Potential DM degradation (a+b) was highest (309.14) at 1.0% of body weight supplementation and so also was the rate constant c (0.02). The regression (R^2) values for DM degradation against incubation time were high and ranged from 0.86, 0.95, 0.87 to 0.99 for 0.0, 0.5, 1.0 and 1.5% pigeon pea supplementation, respectively. Similarly high R^2 values were obtained for potential DM degradation (a+b) and DM intake (0.83), apparent DM digestibility (0.90) and daily weight gain (0.77).

The gas production trial showed increase in the level of gas produced (23.67 – 39.17ml/200mg DM) as pigeon pea forage supplementation increased. Regression of gas production against incubation time was high for all the treatments 0.97, 0.98, 0.99 and 0.95 for 0.0, 0.5, 1.0 and 1.5% pigeon pea supplementation, respectively. Regression of potential gas product (a+b) was moderate for DM intake (R^2=0.61) and apparent DM digestibility (R^2=0.53) but poor for daily weight gain (R^2=0.43). There was highly positive correlation between gas production and DM degradation for all the treatments with r-values ranging from 0.62 to 0.88.

It can be concluded from these studies that yearling ewes cannot maintain weight on rice straw alone. Supplementation with pigeon pea forage improved intake and digestibility. Supplementation at 1.0% body weight enables yearling ewes to maintain weight and also brought about an improvement in the levels of blood and rumen metabolites. Farmers in the northern part o the country who experience extreme feed scarcity during the dry season can therefore use this to maintain live weight of ewes. This will help in reducing the problem of weight fluctuations

experienced by these farmers and the subsequent waste of time and resources, which occur during compensatory growth.

Gas production can be used to predict volatile fatty acid production and DM degradation *in vivo* but it was poor in predicting performance parameters such as feed intake, DM digestibility and weight gain. The potential DM degradation was better in predicting these performance parameters. It is recommended that both gas production *in vitro* and DM degradation *in vivo* should be used as measures of the nutritive value of fibrous feed materials.

CHAPTER ONE

1.0 INTRODUCTION

The detrimental effects of the long dry season in Northern Nigeria on quantity and quality of feed available to livestock are well documented (Alhassan, 1989; Abubakar, 1998). The attendant effect of this feed scarcity on animal performance and productivity in Northern Nigeria is also obvious (Adebowale and Taiwo, 1996). Considering that this area is home to about 80% of the Nigerian ruminant livestock population emphasizes the problem at hand.

Crop residues form a major component of feed resource for ruminant livestock during the dry season. Despite the fairly large availability of these residues (about 71 million tonnes), (Alhassan, 1989), their utilization by animals is limited by low voluntary intake due to bulkiness, low dry matter digestibility and poor nutrient status. Crop residues are known to be high in lignocelluloses, low in available carbohydrate and nitrogen (Girma *et al*., 1994). Supplementation of cereal crop residues with forage legumes has been shown to increase intake (Mosi and Butterworth, 1985), and intake and digestibility (Adejumo, 1987). Rice straw is one of such crop residues.

Rice is principally produced for human consumption and large amounts of straw are left on the field after harvest. Rice straw constitutes a source of carbohydrate for ruminants in countries where it is produced. The production target for rice in Nigeria by the year 2010 is 1,152,000 tonnes (Shaib *et al*., 1997). In South East Asia, rice straw constitutes over ½ of the available food crop residue

(Moran *et al*., 1983). The Food and Agriculture Organization (FAO, 1995) estimated world rice straw annual yield to be about 546 x 10^6mt $year^{-1}$. Most of this (⅔) is burnt as energy source and only about 1/3 is fed to ruminants. Despite the large availability of this crop residue, its utilization is limited by its low intake (31.5g/kg OMI/day) and digestibility (19.9g/kg) (Sujatha *et al*., 1998), low nitrogen, content (3-7%) depending on variety (Anshu *et al*., 1997) and high silica (9-16%) (Bae *et al*.,1997; Jackson, *et al* 1971). It fails very often to meet the animals' maintenance needs (Moran *et al.*, 1983).

Ammonia (Nakashima and Ørskov, 1990), sodium hydroxide (Garret *et al*,1979), alkaline hydrogen peroxide (Myung and Kennelly,1989) and urea (Wanapat *et al*., 1990) have all been used as chemical treatments to improve the digestibility of rice straw and to enhance its utilization. These treatments are technically feasible at the farm level but have not been adopted particularly by the marginal and smallholder farmers because of the difficulty and cost involved (Tingxian *et al.*, 1993).

There is a need, therefore, to seek for new ways of improving the nutritive value and utilization of rice straw without pre – treatment so as to improve efficiency of utilization under conditions occurring in Nigeria.

Dual-purpose legumes such as pigeon pea, offer a good opportunity to integrate livestock and crop production whilst optimizing the returns to input. Pigeon pea is easy to establish and manage. It is flexible in response to

environmental and management variations and would, therefore, likely succeed with farmers' management (Reategui *et al*., 1995).

This plant will go a long way in helping to meet the challenges we face today learning how to produce higher yields of crop and livestock while still conserving essential natural resources like soil, water, forest and biodiversity which will be needed for the survival of future generations.

Objective

This study was therefore carried out to ascertain the nutritive value of pigeon pea forage as a dry season supplement to a basal diet of rice straw fed to Yankasa sheep with the following objectives:

i. To determine the chemical and mineral composition of rice straw and pigeon pea forage, and hence estimate their feeding value in Yankasa Sheep.
ii. To determine the digestibility and nitrogen balance of the experimental diets.
iii. To determine the rumen and blood metabolites profile and levels in relation to the experimental diets.
iv. To determine the nutritive value of pigeon pea forage using *in vitro* gas production technique and hence ascertain its accuracy as a tool for predicting VFA and DM degradation in the rumen.
v. To determine the degradation characteristics of rice straw and pigeon pea forage.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 CROP RESIDUES IN RUMINANT FEEDING.

Nigeria is an agricultural country with diverse vegetation, varying from rainforest to the Sahel. The savanna zone is home to about 80 percent of ruminant livestock population. Availability and quality of feedstuff are major constraints in the development of the livestock industry in Nigeria. The situation is worse during the long dry reason when livestock depend mainly on range and cereal crop residues.

More than 340 million tonnes of crop residues are produced annually in Africa (Mosi and Butterworth, 1985). The intensification of crop production as a result of population increase has over the years increased the quantity of these crop residues. Shaib *et al*., (1997) gave the production target for the year 2010 of the main cereal crops in Nigeria as: maize 1388, millet 5128, sorghum 5977 and rice 1152 (000,000 tonnes per annum). Generally, since the straw: grain ratio of these crops is 2:1, about 256, 450,000 tonnes of crop residues will be made available. These crop residues are potential sources of energy for the ruminant.

The feeding value of cereal crop residue is, however, limited by major deficiencies of protein, metabolizable energy and minerals (Dutta *et al*., 1999). The chemical composition and digestibility of crop residues also, vary greatly depending on species, variety and agronomic practices. Offered alone, cereal straws cannot meet the maintenance requirement of cattle, sheep and goats.

Alawa (1999) stated that an important principle in the feeding of crop residues, especially the poor quality roughages, is that the potential intake and digestibility can only be achieved if certain factors are not limiting. He further stated that nitrogen is often considered the first limiting nutrient to intake by ruminants on low quality roughage feeds. Kabaija and Little (1988) reported that in general, ruminants fed solely on crop residues are unlikely to have adequate sodium intake. These residues according to the authors are likely to be deficient in phosphorus, copper and possibly zinc.

2.2 RICE STRAW AS A CROP RESIDUE

Rice is principally produced for human consumption and a large amount of straw is left on the field after harvest. Rice straw constitutes a potential source of feed for ruminants. In South East Asia, rice straw constitutes over half the available food crop residue (Moran *et al.,* 1983). Many large ruminants, particularly those in Indonesia are fed solely on rice straw and other low quality by-products because the smallholder farmers have neither the capital nor the land to provide anything but a subsistence diet.

Nigeria produces about 1,152,000 tonnes of rice annually (Shaib *et al.*, 1997). About 3,456,000 tonnes of straw is therefore, left on the field. The Food and Agriculture Organization (FAO, 1995) calculated global rice straw production to be 546×10^6 kg/year.

2.2.1 **Chemical composition of rice straw**

Farmers grow different cultivars of rice. Different rice straw cultivars differ in their chemical composition. Doyle and Oosing (1994) attributed such differences to the genetic make up of the plant, which controls morphological characteristics such as proportion of leaf and stem, and also to different management practices during growth or harvest of the crop.

Anshu *et al*. (1997) reported crude protein content of eight varieties of rice straw to range from 4.6 to 7.3 percent. This also, agrees with the result of Jian-xin *et al* (2001), Mosi and Butterworth (1985) Bae *et al*., (1997) and Dutta *et al*. (1999) reported neutral detergent fibre (NDF) and acid detergent fibre (ADF) values of 66.5 to 77.6 and 49.2 to 56.00 percent respectively while Zhiliang *et al*. (1996) reported values of between 35 to 43 and 18 to 23 for rice straw cell content and hemicelluloses respectively with significant differences in the hemicelluloses content of different rice varieties. Doyle *et al*. (1986) pointed out the same effect of variety on the chemical composition and nutritive value of straws. Dutta *et al*. (1999)' reported cellulose content of 34.5 while Moran *et al*., (1983) and Cann *et al*. (1993) obtained gross energy values of 15.9MJ/kg DM and Ahoefa *et al*., (2001) obtained variable ash contents from fifteen varieties of rice straw. The values ranged from 9.6 to 17.1 percent. This is lower than values of 16.6 and 18.6 percent reported for Phillipines and California varieties (Balista *et al*., 1989; Rahal *et a*l., 1997). Silica content of rice straw is high and variable. Walli (1988) and Bae *et al.* (1997) reported between 5 and 16 percent. This agrees with the result

obtained by Vadiveloo and Phang (1996). Processing method particularly during collection of the straw is a major detriment. Sand is often picked along with the straw. This contributes to the silica content of the straw. Also, silica uptake from soil and content in plant depend on its concentration in soil solution and its deposition varies among rice varieties (Vadiviloo, 1992). Abou-El-Enin *et al*., (1999), reported a significant correlation between silica and ash contents. They found that the contribution of silica to ash content was 60.9 percent.

2.2.2 **Uses of rice straw**

In Asia, rice straw constitutes over half the available food crop residue (Moran *et al*., 1983). It is mainly used as roughage in ruminant feed. Many large ruminants particularly those in Indonesia are fed solely on rice straw and other low quality by-products (Parez *et al*., 1978). In these countries, rice straw is an important energy feed for ruminant animals.

Rice straw has been used to improve quality parameters of silage from high moisture materials such as Chinese milk vetch and turnip (Jan-xin *et al*., 2001). Rice straw is used as a mulching material in gardens, thereby, contributing to the organic matter content in soils.

In traditional African societies, rice straw has been burnt for energy especially in areas where firewood is in short supply. Most times it is left in the field for animals to graze (Singh and Kush 1981).

2.2.3 **Factors affecting the digestibility of rice straw**

The main components of rice straw are fibrous cell wall substances consisting of cellulose, lignin and silica. Generally, rice straw contains 50 to 60 percent cell wall and 20 to 40 percent cellular contents (Yantyati *et al*., 1987).

Digestion characteristics of cell wall depend on its own structure explained by the degree of lignification and factors to which the rice straw is exposed in the alimentary tract. Rice straw is unique in that its high silica and lignin content tend to limit cell wall digestibility.

Silica deposited in cell wall varied from 69.1 to 88.9 percent (Widyastuti and Abe, 1989). Silica and lignin contained in cell wall of rice straw are considered indigestive fraction of cell wall since their recoveries were found to be hundred percent in faeces and they are the factors limiting digestibility of cell wall. Shimojo and Goto (1989) found that silica exerts an anti-microbial effect, as shown by the addition of sodium-silicate to mixed cultures of rumen bacteria which was found to reduce digestion of plant cell wall and inhibit cellulose digestion and growth of cellulolytic microbes. This finding suggests that the negative effect of silica on digestion of plant tissue may be related to both the contribution to cuticle integrity and its direct action to prevent colonization of plant tissue by ruminal microorganisms. Silica in cell wall is found to be negatively correlated to digestible organic matter. Yantyati and Akira, (1989) reported that for every one percent increase in silica, digestible organic matter decrease by 0.98 percent.

Both outer and inner surfaces of rice straw leaf sheath contain significant silica and show remarkable resistance to microbial colonization (Yantyati *et al*., 1987). Internal tissues free from silica were readily colonized and digested (Yantyati *et al*., 1987). Silica appears to exert its greatest effect on the ruminant digestive process by maintaining a formidable physical barrier to rumen microorganisms. In the same manner, the lignin which strengthens the vascular bundles may inhibit microbial colonization and delay degradation of these bundles relative to other internal tissues. Other workers, Barry and Duncan (1984), Van Soest (1981) however, suggested that since silica is negatively correlated with lignin, cellulose and hemicelluloses content of straws, the decrease in digestibility of organic matter may be due to a direct physical outcome from the fact that the presence of silica reduces the amount of digestible components in the straw.

The presence of a protective waxy cutin layer overlaying the cuticle is another factor affecting the digestion of rice straw. Many studies have shown that the cuticle is not degraded, but is removed from plant tissue during digestion only by preferential microbial attack on underlying epidermal cells (Akin, 1989). As a result, digestion of chopped forage is essentially limited to damaged region of the cuticle and to cut ends. If rice straw escapes extensive damage during mastication, the cuticle may present the major impediment to microbial digestion of rice straw in the rumen. Rice straw digestion may be realized if the structural integrity of the cuticle can be compromised within the rumen (Moran *et al*., 1985).

Anshu *et al.* (1997) reported that straws of different rice cultivars differ in their pH values. They found that nine cultivars of rice straw whose pH was measured outside the rumen had pH values ranging from 6.6 to 7.45. Grants and Mertens (1992) found that higher rumen fluid pH is conducive for cellulose digestion, thereby, reducing the degradation of lignin-hemi cellulose complex. Nangia and Sharma (1994) also reported that higher rumen pH increases rumen flow rate leading to washing out of old bacteria cultures known for higher hemicelluloses activity. Rumen pH has been found to be negatively correlated with straw solubility (Jian-xin, *et al.*, 2001). Although, the rumen is buffered by inorganic substances such as carbonate and phosphate, acids of fermentation products can sometimes exceed the buffering capacity and pH can decline. Low rumen pH can have deleterious effect on fibre digestion which in turn reduces intake and digestibility. Low rumen pH also causes inflammation of the rumen wall with clumping of the rumen papillae (Ørskov, 1994).

Yantyati *et al.* (1987) found a large decrease in cell wall digestibility at pH below 6.34, and at pH 6.14 cell wall digestion was reduced to about one third of the value of pH 7.04. The growth and activity of cellulolytic bacteria is depressed at pH 6.1. Anshu *et al*., (1997), concluded that determination of the initial pH of the straw could be used to predict the NDF or dry matter degradability for screening large number of cultivars.

2.2.4 **Effect of rice straw feeding on animal performance**

Rice straw is an important energy source for ruminants. In Asia it is estimated that rice straw harvest has the potential to feed over nine million cattle and Buffalo (Tillman, 1981). However, because of its low digestibility and intake associated with low nitrogen, mineral and energy contents, it fails very often to meet the animals' maintenance needs (Anshu *et al*. 1997). The low digestibility coefficient, metabolisable energy content and negative mineral balances obtained when Ongola cattle and Buffalos were fed on rice straw and alkali treated rice straw by Moran *et al*., (1983), demonstrate the inability of ruminants to maintain live weight on a diet consisting solely of rice straw. Sujatha *et al*. (1998) reported organic matter intake of 31.51g/kg/day, 19.9g/kg/day digestible organic matter intake and 468g/kg organic matter digestibility on rice straw. They also reported daily weight loss of -1.7g/kg$W^{0.75}$/day and nitrogen balance of -74mg/kg$W^{-0.75}$/day for sheep fed solely on rice straw. Moran *et al*. (1993) obtained dry matter intake of 74.9 and 73.4g/kg$W^{0.75}$/day for Ongola cattle and Buffalo fed solely on rice straw. The digestibility coefficient of dietary nutrients were 37.6, 46.0, 41.6, 24.4, 55.4, 42.8 and 11.2 percent for dry matter, organic matter, energy, nitrogen, crude fibre, ether extract and ash, respectively.

The work of Rahal *et al*. (1997) showed varietal differences in voluntary intake and *in vitro* digestibility of different cultivars of rice straw. Their results showed a range of between 850 and 863kg dry matter intake per day, 490 and 587g/kg organic matter digestibility, 2.1 and 2.7g/kg organic matter intake and 1.0

and 1.3g/kg digestible organic matter intake for three rice cultivars. The nylon bag organic matter and neutral detergent fibre degradability (72hrs) of straw of seven rice cultivars ranged between 547 and 597g/kg dry matter, and 439 and 540g/kg DM, respectively.

2.2.5 **Methods of improving the utilization of rice straw**

There has been much interest in methods of improving the utilization of rice straw by animals particularly in countries where rice is grown in large quantities. These methods range from the growing of rice cultivars with low lignin and silica content which could improve the digestion of the straw (Tingxian *et al*., 1993, Ahoefa *et al*., 2001) to the study of fibre characteristics of cultivars of rice straw, (Zhliang *et al*., 1996) and the application of various treatments to the straw. Among such treatments are the use of alkali, ammonia, and urea. Supplementation with concentrate and/ or forage is also practiced. The effects of alkali treatment on straw have been summarized (Cann, *et al*., 1993) as the cleavage of linkages between lignin and other cell wall constituents, acids, swelling of cell wall and partial solubilization of hemicelluloses, lignin, protein and silica. This causes changes in the fragidity of parenchyma layers. Nakashima and Ørskov (1990), reported that an improvement in the digestibility of rice straw was obtained by solubilization of silica with hot solution of neutral sodium salts. Sodium hydroxide (Garrett et al.,, 1979), alkali hydrogen peroxide (Myung and Kennelly, 1989) and urea (Wanapat *et al*., 1990) have all been used

as chemical treatments, to improve the digestibility of rice straw and to enhance its utilization by ruminants.

Ammonia treatment, however, has an advantage over alkali treatment because, when the digestibility is increased by structural changes with ammoniation, ammonia absorbed into straw will fulfill increased microbial requirement for nitrogen.

Urea treatment however, requires large quantities of water. Water is a principal constraint of the production system in the savanna zones of Nigeria. Also ammonia loss could be up to 60 percent when straw is treated with urea. Such losses cannot be justified under condition of limited nitrogen supply (Nakashima and Ørskov, 1990).

Results obtained (Moran *et al;* 1983, Cann *et al*., 1993 Anshu *et al.*, 1997) showed improvement in intake of rice straw of between 10 and 20 percent and digestibility of between 30 and 50 percent when rice straw was supplemented with *leuceana* or treated with ammonia. These treatment methods have been found to be technically feasible at the farm level but it has not been adopted particularly by the marginal and small scale farmers for a number of reasons such as the chemicals are too costly, some can be poisonous and most farmers lack the technical knowledge needed for such treatments.

The use of concentrates has also been tried. Apart from the cost implication to the small scale farmer, there is high competition for such concentrates for monogastrics (Alawa, 1999, Hunter and Siebert, 1980). Other

sources of nitrogen such as browses and legumes are now gaining importance. The self reliance of the farmer in the source of nitrogen therefore, is a prerequisite to improving the efficiency of utilization of cereal residues and the productivity of animals. (Premaratne *et al.,* 1998).

It was shown that forage legumes in addition to correcting their deficiency of rumen degradable nitrogen if supplemented to cereal stover, can contribute a substantial amount of rumen degradable organic matter and minerals (Reed *et al.,* 1990).

2.3 LEGUMES AND THEIR USES IN LIVESTOCK PRODUCTION

2.3.1 Significance of Forage Legumes as Protein Supplement

To overcome constraints to the efficient utilization of agricultural by-products as animal feed, interest is now placed on the use of forage or dual purpose legumes as supplementary feed. The biological aspect of utilization of crop residues with the aid of nitrogen supplied by leguminous forages could receive more response from the subsistence farmers since the intervention is compatible with the long term productivity of cereal crop. This is due to the improvement in soil fertility resulting from ability of legumes to fix nitrogen in the soil. The leaf fall at maturity not only adds to organic matter in the soil but also provides additional nitrogen. Kumar-Roa *et al* (1981), reported residual nitrogen of approximately 40kg/ha. Since nitrogen is also the most limiting nutrient in the soils of Nigeria, the production of dual purpose legumes could result in an increase in cereal grain yield which is accompanied with rise in residue yield. Forage

legumes could, therefore, serve as the key link for effective integration of animals into the strong crop oriented production system in Nigeria.

Forage legumes can also serve as a source of sulphur which is usually lacking in low protein roughage diets (Miller, 1982). The supply of roughage diet with sulphur an essential element for ruminant microbes showed increases in the digestion of cellulose (ARC, 1990). Although ammonia is the major source of nitrogen for microbial growth, some species in the rumen are unable to utilize it and so require peptides and or amino acids for growth (Pisulewski *et al*., 1981). These cannot be supplied when non-protein nitrogen (NPN) supplements are used.

Due to variations in degradation, many protein nitrogen sources release ammonia at lower rate than urea-nitrogen, more closely coinciding with release of energy from the cellulose component thus enhancing microbial production. This in turn stimulates increased rate of cellulose digestion and voluntary intake.

The synchronization of rate of degradation of nitrogen and balance of carbohydrate components in the rumen is important for the synthesis of microbial protein (Roffler, *et al* 1976). Microbial protein in the rumen is the major source of nitrogen to the host animal, accounting for 60-85 percent of the total amino acid entering the small intestine (Ørskov, 1982). The pattern of degradation, therefore, influences the choice of nitrogen source for efficient utilization of cereal residue.

The presence of nitrogen in forage legumes however, does not always guarantee its availability to the target microbes in the rumen. Research by the International Livestock Centre for Africa (ILCA, 1987) showed that the content of

insoluble proanthocyanides and soluble phenolics in legumes are related to nitrogen digestibility. Browse with moderate levels of phenolic compounds such as leaves of *Acacia brevispics, Acacia. seyal* and *Acacia. nilotica* and fruits of *Acicia. albids* and *Acicia. tortilis* are promising protein supplements, although the phenolics in these species also reduce nitrogen availability. The negative effect is partially offset by lower urinary loss of nitrogen, allowing adequate animal performance (Kumar and Singh, 1984).

Forages rich in condensed tannins such as *Acacia aneura* may have a negative impact on animal performance even if these species represent a small proportion of the diet (Pritchard *et al*., 1988). A primary manifestation of an adverse effect is the depressed intake of metabolisable energy. This occurs principally due to a reduced voluntary dry matter intake as a consequence of impaired rumen fermentation of cellulose and hemicelluloses (Barry and Duncan, 1984), while occasionally, animals were found to lose weight or died (Kaitho *et al*., 1998).

2.3.2 **Effect of legume supplementation of crop residues on animal performance**

2.3.2.1 **Maintenance of body weight**

Alawa (1999) observed that while ruminants may survive by grazing low quality roughage during the dry season in tropical countries where little or no supplementary feeding is practiced, losses in body weight, difficult to quantify are likely to occur. It was suggested that animals may maintain their weights by

increase Singh the intake of crop residue and other low quality by-products if protein with moderate degradation within the rumen is reasonably supplied. Richard *et al*. (1994) also stated that protein supplementation of crop residue containing low nitrogen levels has increased forage intake and animal performance. However, protein degradation characteristics of feed ingredients, as well as interactions between nutrients in feed ingredients are important determinants of response to supplementation (Brown and Pitman, 1991). In some cases a low level of (10-20%) supplementation of tropical grasses with tree legumes has increased animal efficiency without significant increase in dry matter intake.

2.3.2.2 **Increase in dry matter intake**

Moran *et al*., (1983) reported that dry matter intake increased when rice straw was supplemented with *Leuceana leucocephala*. Manyuchi *et al.*, (1997), reported that forage supplementation increased total feed intake but as the level of supplementation increased beyond 20-40 percent, the intake of the basal diet fell below the level achieved with the un-supplemented basal diet. This agrees with the result of Mosi and Butterworth (1984) in which increasing the inclusion of *Trifolium tembense* hay above 34.7 percent to a basal maize stover diet decreased the intake of maize stover from 15.1 to 12.2g/kg/day.

There appears, however, to be differences in the level of response depending on the type and level of forage supplementation. Sujatha et al., (1998), fed three types of forages: *Leuceana leucocephala*, *Gliricidia* and *Trifolium*

tembense hay and obtained variable responses of 35.4, 36.1 and 36.6g/kgW$^{0.75}$/day for *Leuceana*, *Gliricidia* and *Trifolium* forage supplement respectively as against rice straw basal intake of 31.5g/kgW$^{0.75}$/day. The work of Dutta *et al.,* (1999), also showed similar results. Dry matter intake of rice straw was highest with *Leuceana* supplement followed by *Prosopis* and least for oat straw. The increase in dry matter intake was approximately 40.51 percent and 20.65 percent in the *Leuceana* and *Prosopis* supplemented groups, respectively. These workers attributed these differences not only to the effect of increased dietary crude protein, but to their readily fermentable fibre content. Mehrez and Ørskov (1977), reported that animals fed on crop residues as their sole diet show low dry matter intakes with decline in body weight. The nature of the basal diet also affects response to supplementation. Mosi and Butterworth (1985), fed three different crop residues (oat tef and wheat) with varying levels of *Trifolium tembense* hay. Results obtained showed that Tef straw had more total dry matter intake 27.9 to 32.2 g/kg compared to oat straw 26.4 to 29.8g/kg and wheat straw 24.1 to 27.5/kg. These differences could be due to the differences in nature of the fibre constituents of the basal diet. They concluded that plant cell wall content is a major determinant of intake.

2.3.2.3 **Increase in rumen degradable protein**

Alawa (1999) stated that, to evaluate various protein supplements in terms of the extent to which they meet the needs of the rumen microbes depends on the ruminal degradability of the protein. He further explained that the proportion of

protein broken down in the rumen (RDP) varies with protein sources and depends on a variety of factors. Some of the factors stated are: structural characteristics of the protein, process Singh method, rumen retention time, nature of the basal diet and rumen ammonia concentration. The degradation of dietary nitrogen which determines rumen ammonia – nitrogen evolution has been implicated in the intake of food. Newbold (1985) as cited by Alawa (1999) obtained a highly significant linear relationship between feed intake and dietary rumen degraded protein concentration. Alawa and Hemingway (1986) also reported an increase in feed intake when rumen-ammonia nitrogen increased from 4.6g RDP to 14.4g RDP. A decrease in protein degradability implying reduced rumen ammonia nitrogen has been associated with reduced ruminal microbial population and fermentation thus, leading to reduced feed intake.

It is well documented that the utilization of the energy component of crop residues by ruminant animals is highly dependent on the efficiency of the fermentative activity of the microbes in the rumen. For optimum fermentation on a given diet, a certain level of ammonia concentration in the rumen is required. Otherwise, feed intake may be reduced if ammonia concentration limits the rate of fermentation.

2.3.2.4 **Improvement in digestibility**

Results of legume supplementation of low quality forage on digestibility have been variable. Cann *et al*., (1993), reported significant increase in the digestibility of maize stover and oat straw when supplemented with *Trifolium*

tembense hay but no increase in digestibility when *Trifolium tembense* hay was used to supplement Tef straw and wheat straw. They attributed these differences in digestibility to the content of lignin and silica in the cereal straws. According to their study, wheat straw had the highest level of lignin and silica and had the lowest digestibility. Their result also showed that the improvement in the digestibility of the diets occurred at different levels of supplementation. Successive increment of *Trifolium tembense* hay caused an increase in digestibility with the exception of the highest level in animals fed on oat straw and Tef straw. This implies that digestibility increases with increase in the level of crude protein in the diet up to a point. Once the nitrogen deficiency of crop residues has been overcome, there may be little advantage in feeding additional forage legume. Given a satisfactory level of nitrogen in the diet, the amount of protein synthesized by the rumen microbes and the rate at which they ferment roughages is limited primarily by the amount of readily available energy in the feed. Agricultural Research Council (ARC, 1984), stated that with a readily available energy source, microbial protein yield is related to the amount of organic matter digested and vice versa.

Supplementing rice straw with *Leuceana*, *Gliricidia* and *Trifolium tembense* hay increased organic matter digestibility of the whole diet compared to the control (Premaratne, *et al*., 1988). Organic matter digestibility increased from 488g/kg for the control to 516, 526 and 557g/kg for *Leuceana*, *Gliricidia* and *Trifolium tembense* hay, respectively. Dutta *et al.* (1999), found that goats

exhibited a significant depression in crude protein and organic matter digestibility and nitrogen utilization of rice straw diets supplemented with *Prosopis cinerano*. This according to them may be due to higher total tannin (7.0% DM) and fibre content of *Prosopis* leaves.

2.3.2.5 **Improvement in growth rate**

Perez *et al*., (1978) reported growth rate of 0.38kg/day in Zebu bulls fed *ad libitum* on 60 percent rice straw and 40 percent *Leuceana* with dry matter intake of 105g/kg$^{W0.75}$/day but found that increasing *Leuceana* to 90 percent of the total diet did not increase appetite or growth rate. Young cattle were unable to maintain live weight when fed unimproved carpet grass. The addition of protein pellets increased body weight, indicating that this form of supplementation removed the major nutritional limitation imposed by the basal diet. Working with sheep, Premarantne *et al*., (1998), reported a loss in weight of 1.7g/kgW$^{0.75}$/day when fed solely on rice straw but supplementation with *Leuceana*, *Gliricidia* and *Trifolium tembense* hay resulted in a daily weight gain of 5.2, 5.4 and 4.7g/kgW$^{0.75}$/day respectively.

In Nigeria Adamu *et al*.(1993) introduced S*tylosanthes harmata* cv. *Verano* and *S. guianesis* cv. *Cook* into the natural range to be used as dry season supplements for stressed animals in the form of fodder. They reported decrease in cattle weight loss in the dry season and improvement in conception and milk production. Yashim (2006) evaluated the nutritional value of C*entrocema pascuorum* as supplement, he reported daily weight gain of 7.14g in sheep

2.3.3 **Anti-Nutritive Factors in Leguminous Forage**

Most browses and forage legumes are known to contain simple or complex phenolic compounds (Kaitho *et al*., 1998). Wiegand *et al*., (1995), stated that the differences in response noted when leguminous fodders are fed as protein supplements have been attributed to differences in the levels of phenolic compounds. According to Robbins *et al*., (1987), browse species of tropical legumes associated with anti-nutritional factors in livestock nutrition act via direct toxicity, reduced palatability and/or reduced digestibility of the feed. Kumar and Singh (1984), stated that although much still needs to be known particularly with regards to the components causing reduced palatability, the anti-nutritional factors implicated thus far include polyphenolics, cyanogens, saponins, non-protein amino acids, phytochaemagglutanins (lectins), alkaloids, triterpense and oxalic acids. He further reported that there are about 8,000 polyphenols, 270 non-protein – amino acids, 32 cyanogens, 10,000 alkaloids and several saponins which occur in various plant species. Of these, polyphenolics (tannins) make the largest contribution.

Tannins are broadly divided into two groups hydrolysable tannins, which are more susceptible to enzymatic and non-enzymatic hydrolysis and usually more soluble in water, and proanthocyanidins which are not susceptible to hydrolysis. Proanthocyanidins are more commonly referred to as tannins.

2.3.4 **Effect of Tannins on the Nutritional Value of Forage Legumes**

Mueller-Harvey and McAllan (1992) and Reed *et al*. (1990) reported that tannins in forage legumes have both positive and negative effects on nutritive value. Tannin in high concentration causes the following:

2.3.4.1 **Reduction in feed intake**

Reduced feed intake may be caused by a decrease in palatability. During disintegration of plant material, such as chewing by ruminants, tannins interact with salivary glycoproteins to form insoluble tannin-protein complexes (Getachew *et al*., 2000). Further binding to protein may occur in the rumen (pH 5.5-7.2). This astringency increases salivation and decrease voluntary feed intake. Donnelly and Anthony (1969) reported that the tannin level required for rejection by grazing animals is about 20mg/g of dry matter. The work of Maldonado *et al*., (1995), however, showed that pH alone is not the only determinant of tannin-protein complex formation since precipitation occurred in the pH range of 6-7 only when background of inorganic ions were present. Some workers (Oh and Hoff, 1987; Murdiati 1991) reported that tannin: protein ratio and ionic strength do not have significant effect on tannin-protein complex formation, but the presence of calcium, magnesium, sodium and potassium is known to improve the activity of extracted leaf riboluse biphosphate carboxylase and increase the facility for the formation of insoluble tannin – plant protein complex. The work of Maldonado *et al*., (1995) also showed the importance of inorganic ions in the formation of tannin-protein complex at pH values normally found in the rumen. They further

stated that when the ratio of pure tannin to protein exceeds 1:1, there is sufficient tannin to precipitate all available protein. There are, however, differences in this affinity depending on tannin type and nature of the protein.

Legume plants with high content of proanthocynadins are associated with low straw intake in sheep (Reed and Woodward, 1990).

2.3.4.2 **Reduction in digestibility**

Tannins in feed reduce the digestibility of dry matter and nitrogen. Reed (1995) reported negative digestion coefficients for neutral detergent insoluble nitrogen (NDIN) and acid detergent lignin (ADL). Reed *et al*. (1990), had earlier reported similar results. They observed negative digestion coefficient for NDIN in sheep fed diets containing forage from *Acacia cyanophylla* and *A. sieberiana* that had high levels of tannins. Sheep fed sorghum silage with 18.7g tannin/kg had depressed digestion of crude fibre and less microbial activity in the rumen when compared with sheep fed with maize silage containing 6.6g tannin/kg (Tagari, *et al.* 1976). The threshold of toxicity of tannic acid added directly to rumen content in fistulated animals was 3-5 percent in cattle and 8-10% of diet in goats apparently because goats, produce an active tannase in the rumen mucosa (Bejovic *et al*., 1978).

The chemical and biochemical nature of tannins seems to have an effect upon protein digestibility. Kumar and Singh, (1984) reported differences in the digestibility of protein of tree leaves vis-à-vis their total tannin content. They

attributed these differences to the chemical and biochemical nature of the tannin, their protein precipitating capacity and degree of polymerization.

In most non-taninferous feeds, the true digestibility of nitrogen is approximately 93 percent (Van Soest, 1982). For some browses, true digestibility of nitrogen ranged from 52-94 percent (ILCA, 1988). Condensed tannins protect carbohydrate against ruminal fermentation. They may also complex with carbohydrate substrates, especially cellulose. Tannin from *sainfoin* inhibited the cell-associated protease activity of *streptococcus* bovis and *Butyrivibrio fibrosolvens* but not in *Prevotella ruminicola* or *Ruminobacter amylophilis*. Tannin can also induce changes in the morphology of several species of ruminal bacteria as shown by electron microscopy (Jones *et al*., 1994). The non-uniform behaviour of the protein in browse plants causes a problem in their use as source of protein and emphasizes the need to understand the chemistry of tannin-protein interactions.

The depressive effect of tannin in browse on ammonia nitrogen concentration *in vivo* has been reported by various workers (Getachew *et al*., 2000, Osakwe *et al*., 1998). When tannin containing browses were incubated alone in low nitrogen, the net production of ammonia nitrogen ranged from 3.2 to 21.8 mg/l. The addition of polyethylene glycol (tannin binding agent) dramatically increased the ammonia nitrogen level as well as the amount of short chain fatty acids (SCFA) (Getachew *et al*., 2000). Durand (1989), however reported ammonia

nitrogen concentration of 5 to 28mg/l as being optimum for ruminal cellulolytic bacteria. Alawa (1991), stated that while the rumen ammonia nitrogen concentration necessary for maximal microbial synthesis appears unresolved, appropriate levels for maximal microbial fermentation of low quality roughage diets have been defined by Satter (1974) and Allison (1970), as 5mg/100ml rumen liquor and 5-8 mg NH_3/100ml rumen liquor, respectively.

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

Getachew *et al.* (2000), compared plasma urea-nitrogen level with levels of urinary nitrogen in sheep and goats, the correlation between plasma urea nitrogen and urinary nitrogen was high in sheep (r=0.75) but low in goats (r=0.19). Also, urinary nitrogen was markedly lower in goats which suggest that goats may be able to recycle more urea to the rumen than sheep at high levels of plasma urea nitrogen.

Tannins are potent inhibitors of digestive enzymes due to their capacity to bind with enzymes. It was reported that water soluble substances in the leaves of *S. lespedeza* inhibit the enzymatic hydrolysis of cellulose (Cope *et al*., 1971). Henis *et al*. (1971) studied the effect of aqueous extract of carob pods upon the growth and morphology of microbes and found that their tannin fraction exert both bacteriostatic and bacteriocidal effects on *Cellvibrio fulvus* (acellulolytic bacteria). Phosphate utilization by rumen microbes is also decreased with increase in tannin concentration in the diet (Kumar and Singh, 1984). A poor protein disappearance rate due to high phenolic content of spent tea leaves by *in vivo* ruminal microbial fermentation has been observed (Jayasuriya *et al*., 1982).

Tannin also diminished the permeability of the gut wall by reacting with the outer cellular layer of the gut (Mitjavila *et al*. 1977). This could decrease the digestion of other nutrients. Tannins could decrease the absorption of essential amino acids when present at high concentration. The most susceptible amino acids are methionine and lysine. Decreased methionine availability could increase the toxicity of other compounds such as cyanogenic glycosides because methionine is involved in the detoxification of cyanide via methylation to thiocyanate (Reed, 1995).

2.3.5 **Positive effects of tannins**

A possible mechanism for the defense against the negative effects of tannins in ruminants is the secretion of prolin rich salivary protein and glycoprotein (Getachew *et al*. 2000). Robins *et al*., (1987) carried out studies on

deer, sheep and cattle and showed that salivary glycoprotein, could be involved in the utilization of forages that contain tannins. Prolin rich salivary protein and glycoprotein have a high affinity for tannins. However, Austin *et al*. (1989), reported that salivary protein from sheep and cattle do not produce tannin binding protein.

Tannin may complex proteins at the pH of the rumen (pH 6-7) and protects proteins from microbial enzymes. These complexes are unstable at the acid pH of the abomasum and thus the protein may become available for digestion eventually. Tanner *et al*. (1994), showed that tannin in *Lotus pedunculatus* are associated with an increased flux of amino acids through the abomasum. However, research with non-ruminants indicate that tannins decrease the absorption of amino acids especially methionine and depresses growth.

Beever and Siddons (1985), and Reed *et al*. (1990) hypothesized that tannins increase microbial yield. Several researchers have observed increase in non-ammonia nitrogen (NAN) flow to the duodenum greater than nitrogen intake for forage legumes that contain tannins. Since nitrogen is not created in the rumen, part of increased flow of NAN must be from endogenous sources that have been incorporated into the microbial fractions. Tannins in moderate concentration are also reported to prevent bloat (Reed, 1995).

Tannins reduce nitrogen availability enough to slow rumen fermentation thereby resulting in little excess ammonia. They consequently lower plasma urea nitrogen and thereby reduces loss of nitrogen in urine. Another advantage of

browse plants is that the lower fermentation of nitrogen contained in them helps improve the utilization of crop residue which also ferment slowly.

Reed (1995), Reed and Woodward (1990) suggested the possibility of animals synthesizing tannin resistant enzymes and biodegradation of tannins. The mechanism, by which this occurs, is however, not understood.

2.3.6 E**ffect of tannin on gas production**

The presence of tannin depressed the *in vivo* gas, short chain fatty acids (SCFA) and volatile fatty acid (VFA) production (Khazaal *et al.*, 1994). These parameters could be used to determine the rate of digestion of a feed material (Getachew *et al*., 2000). Sandanandan and Arora (1979), had earlier reported decreases in rumen VFA, microbial deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) production as the concentration of tannic acid increased in the diet. The depression in the fermentation could be the result of either direct interaction between tannins and bacteria cell wall (Jones *et al*., 1994), or the effect of tannin on microbial enzymes. The higher production of SCFA from straws compared to browses indicated the low energy value of browses.

2.4 PIGEON PEA PRODUCTION AND USE IN LIVESTOCK INDUSTRY

2.4.1 Importance and uses of pigeon pea

Pigeon pea fixes nitrogen in the soil. Its leaves which fall at maturity not only add to the organic matter in the soil, but also provide additional nitrogen. Kumar-Roa *et al*., (1981), reported soil residual nitrogen of approximately

40kg/ha. Due to the outstanding deep and lateral spread of its root system, pigeon pea is often called the biological plough. This is because its root system is reported to penetrate and crack the soil. Root depth in pigeon pea is estimated at between 60 and 90cm (Reddy and Virmani, 1981). Extensive ground cover by pigeon pea prevents soil erosion by wind and water, encourages infiltration, minimizes sedimentation and smothers weeds.

Pigeon pea is used in a wide variety of ways. Its main use in the Indian subcontinent, which accounts for 90 percent of the world production, is as human food. The dry seed is de-hulled and the split cotyledons (dhal) are cooked to make soup often eaten with rice.

In Africa and Central America, whole dry seed with or without seed coat are cooked. Sometimes sprouted seeds are consumed. Other times the seeds are processed into flour and used for baking. Green seeds are cooked as vegetables while tender pods (1cm long) are cooked whole in Brazil. In Thailand, Indonesia and America the green peas are also processed and canned (Singh and Kush 1981).

Seed husk, and pods are commonly fed to cattle and green leaves used as fodder. After harvesting the mature pods, plants are often left standing on the field for animals to consume the new flush produced.

The pigeon pea stem serves as important household fuel. Pigeon pea sticks are also used for field fence, huts and baskets. With the increasing shortage of fuel wood in villages, pigeon pea sticks are likely to be in demand and many small holder farmers are likely to grow it (Sharma and Jodha 1982).

In some parts of India and Africa, pigeon pea is often grown as a perennial crop to mark field boundaries. The tall perennial plant also serves as wind break. The use of pigeon pea as a shade in nurseries is also known. Recent ICRISAT studies indicate that pigeon pea has excellent potential for use in agro-forestry system (Sharma and Jodha 1982).

Nene and Sheila (1999), reported that in the state of Assam in eastern India and Thailand, pigeon pea crops grown for two to three years serve as an important host for the scale insect that produces lac. It leaves according to them are also used to feed silkworm.

The medicinal uses of pigeon pea are extensive. Dry roots, leaves, flowers and seeds are used in different countries to treat a wide range of ailments of the skin, liver, lungs and kidney (Faris and Singh, 1999).

2.4.2 **Pigeon pea as a leguminous forage**

There is dearth of information concerning the origin of pigeon pea *Cajanus cajan* (L.). De (1974), reported that pigeon pea originated from India. This was based on the presence of several wild relatives and diversity of the crop gene pool, ample linguistic evidence, few archaeological remains and the wide usage in daily cuisine. Other authors Rachie and Roberts, (1974) considered Eastern Africa as the centre of its origin. This they attributed to the wild occurrence of the plant in Africa. The name pigeon pea is said to have originated in America because the seed was favoured by pigeons.

Pigeon pea plants have been spotted in many countries of the world, but only in a few countries is pigeon pea grown as a field crop and fewer countries report statistics of its production. India dominates world pigeon pea production (Over 90%; Mueller *et al*. 1999). Other countries are Malawi, Uganda, Nigeria and other East African countries, Nepal and Myanmer in Asia, Dominican Republic and United States of America.

Pigeon pea like other pulses is considered a subsistence crop in the cropping systems of India (Sharma and Jodha, 1982). Its cultivation is often relegated to marginal soils, intercropped or in mixed farming systems. Pigeon pea production has increased from 1.7mt in 1950/51 to 2.3mt in 1986/87. Yields have varied between 0.4 and 0.8t/ha. Mueller *et al*. (1999), gave land estimate under pigeon pea cultivation as about 10.3 percent of cropped land in India in 1960/6l and 14 percent in 1986/87. Pigeon pea consumption is about 10g/caput/day in India. Badinger and Mag, (1981), reported that the Indian human consumption of pigeon pea seeds was between 35 and 40g/day. Food and Agriculture Organization (FAO 1987), reported 15 - 29 percent protein in the seed. This provides an equivalent of less than 10% protein and 5 percent energy in their diet.

2.4.3 **Forage yield of pigeon pea**

The potential of pigeon pea to produce forage is demonstrated by the 40t/ha of dry matter obtained in one cutting of late, maturing variety in northern India (Singh and Kush, 1981). Similar result was also reported in northern Nigeria (Akinola, *et al*., 1975). Harrera *et al*., (1966), obtained 57.6t/ha dry matter in

Columbia. Similar yield of 51t/ha was obtained by Parbery, (1967), at two harvests at 220 and 352 days after sowing. These yields are the highest recorded for a forage legume, higher than those of *Leuceana leucocephala* and equivalent to high yielding tropical grasses provided with adequate nitrogen fertilizations. The actual yield of edible forage is about 50% of this amount because of the woody stem (Whiteman and Norton, 1981). Pigeon pea plant should be cut at 0.15 – 0.3m from the ground level (Akinola *et al*., 1975).

Forage yield increases as interval between harvest increases. Akinola and Whiteman (1997), gave optimum date of harvest to be 8 -12 weeks post planting. They also reported that long duration varieties were better adapted to cuttings so long as the lower leaves remain on the stubble.

The variety, sowing date, sowing density and growing condition all influence the yield of dry matter (Akinola *et al*., 1975). The above authors also suggested that the factors mentioned should be taken into consideration. The osmotic adjustment ability of pigeon pea enables continued growth and survival as plant water deficit increases. However, pigeon pea like other crops will yield poorly or may not yield at all if drought/stress is severe and persistent during reproductive growth (Singh and Kush, 1981). It is possible to obtain multiple harvests by allowing the crop to continue growing after harvesting the first flush of pods. Early planting ensures not only high yield from the first flush but subsequent flushes under both rain fed and irrigated conditions (Chauchan, 1987).

Report from Hawai indicated that pigeon pea gives ten times the yield of alfalfa (Embong and Ravoof, 1978).

2.4.4 G**razing potential of pigeon pea**

There are two main methods of grazing pigeon pea. These are by either regularly grazing the vegetative growth at intervals or by using the growth as standing forage for the dry season. As a stand - over crop, pigeon pea provides fodder at a time in the season when there is a deficit of energy and protein for the animals (Whiteman and Norton, 1981). Carrying capacity of a good pigeon pea stand ranged from 1.2 to 3.7head/ha.

Even though productive stands have been maintained for up to 5 years, loss of yield in the second and subsequent season in several grazing trials suggest that pigeon pea is best used as an annual forage crop (Norman *et al*., 1980, Whiteman and Norton, 1981).

2.4.5 A**nti-nutritional factors in pigeon pea**

Singh (1988) reported that pigeon pea contains considerable amount of polyphenolic compounds mainly tannins that inhibit the activity of the digestive enzymes, (trypsin, chymotrypsin and amylase). He further stated that oligosaccharides are also found in pigeon pea. These are much higher in pigeon pea cultivars with dark seed coats. His study showed that pigeon pea contains considerable amounts of unavailable carbohydrate that are known to reduce bioavailability of some nutrients. Pigeon pea also contains phytolecitins but they

are highly sensitive to heat treatment and hence may be of little significance. The glycosides contents of pigeon pea are not at toxic levels (Singh 1988).

2.5 MICROBIAL DIGESTION IN RUMINANTS

Ruminants feed mainly on roughages, which are mainly composed of polysaccharides such as cellulose, hemicelluloses and pectin. These are the primary sources of energy in forage based diets. In the cell wall, the ratio of cellulose to hemicelluloses is 0.8:1 to 1.6:1 (Wilkie, 1979). The forage material, however, contains not only the nutrients required by the animal but also naturally occurring plant secondary compounds such us polyphenols, saponins and silica (Wang *et al*., 2000). Cellulose is the most abundant polysaccharide in the cell wall, accounting for 20 to 30 percent of the dry weight of most plant cell walls (Wang and McAllister, 2002).

Upon ingestion by ruminants, feed enters the rumen and are degraded to various extent by rumen bacteria populations. The ruminal ecosystem is made up of diverse, symbiotic population of obligatory anaerobic bacteria, fungi and protozoa (Feris and Cheng, 1992) that have adapted to survival in the face of high dilution rates, high cell densities and protozoan predation. Bacteria and fungi contribute approximately 80 percent of the degradative activity and protozoa 20 percent (Wang and McAllister, 2002).

The fibrolytic bacteria are generally considered as the primary organisms responsible for degradation of plant cell wall in the rumen (Feris and Cheng,

1992). Compared to bacteria, the role of fungi is not clearly understood. Ruminal fungi are, however, known to produce a broad array of enzymes that generally degrade a wider range of substrates. Fungi also possess the unique capacity to penetrate the cuticle at the plant surface and cell walls of lignified tissues (Akin, 1989). The activity of ruminal protozoa contributes significantly to the digestion of plant cell wall polymers and their absence from the rumen may have a negative effect on the extent of fibre digestion (William and Colemen, 1991).

Degradation and metabolism of structural carbohydrates is accomplished through synchronous activities of the multitude of microbial enzymes present in the rumen. It arises not only from the diversity of the microbial community but also from the multiplicity of fibrolytic enzymes produced by individual micro-organisms (Wang and McAllister, 2002). Efficient digestion of complex substances in the rumen requires the coordinated activities of these enzymes. Contact between these enzymes and their feed substrate is necessary for hydrolysis to occur.

Rumen contents comprise a heterogenous mixture of liquid and solids. Polysaccharide degrading enzymes secreted into liquid fraction are at the risk of inactivation by proteolysis or of being washed out of the rumen before they contact their substrate. Attachment to feed particles is the most efficient way for the microbes to prolong their residence in the rumen and to bring their enzymes into contact with substrate. Brock *et al*., (1982), reported that hemicelluloses and

cellulose activities are notably higher in the particulate fraction of ruminal contents than in the fluid.

Synergism between microorganisms in the rumen have been reported. Dehority (1993), defined it as the increase in activity that exceeds the additive effect of each individual organisms when two or more microorganisms function in the same fermentation. This could occur either through “unmasking” or end product utilization (Wang and McAllister, 2002). This is exemplified by the action of enzymes in the digestion of forages by physically disrupting the lignified stem tissue and allowing entrance of the rumen microbes into plant stems.

While it is often an advantage to encourage dietary protein and fat to pass through the rumen undegraded, post ruminal digestion of carbohydrate often gives more problems for ruminants than it solves (Ørskov, 1994). The capacity for intestinal starch digestion and glucose absorption is low and utilization of exogenous glucose is also limited.

2.5.1 **Limitations of cellwall digestion by rumen microorganisms**

Although ruminants have evolved a powerful and sophisticated microbial ecosystem to digest fibrous feedstuffs, ingested cell wall polysaccharides are rarely completely degraded by the ruminal micro flora. Reasons for this incomplete digestion include the combination of the biochemical and physical barriers present in the ingested substrate and limits of retention time on the ingested substrate in the rumen. Certain feed components such as phenolics, silica, saponins and lignin have negative effects on cellulolytic activity (Bae *et al*.,

1997). Wang and McAllister, (2002) however, stated that the greatest obstacle to cell wall degradation in the rumen is likely to be the cross linkages among cellulose, hemicelluloses, lignin and other compounds that limit the access of enzymes to the substrate trapped inside. Additional evidence suggests that concentration of these materials on the surface of feed particles may prevent microbial attachment.

Limited retention time in the rumen represents a second impediment to complete digestion of plant cell wall materials. The larger the particle size the longer the feed particles are likely to be retained in the rumen and the greater the resulting degradation. Retention time, therefore, affects the extent rather than the rate of digestion.

The outer layer of epicuticular waxes, cuticle and pectin of grasses, legumes and cereal grains also represent a potent barrier to penetration by ruminal microbes. Although, the cuticle is resistant to microbial and digestive enzymes in the rumen, Akin (1989), reported that mastication of forages and pretreatment of cereal grains disrupt the cuticles layer minimizing its deleterious effect on digestion.

2.5.2 **Evaluation of forage digestion by gas production**

Ruminant animals generally consume large quantities of forage in their diet. Valentine *et al*., (1999) stated that the ability to ration cattle and sheep according to requirement depends to a large extent on the accuracy with which the quantity and quality of forages offered and consumed can be estimated. The

ability to accurately predict the nutritive value and potential ingestion and thus improve estimation of requirement for supplementary feeds will result in improvement in performance.

Many methods which estimate digestibility exist to predict the nutritive value of forages. *In vitro* techniques include evaluation of rumen fermentation Singh rumen fluid as developed by Tilley and Terry (1963) or in the gas production method (Menke *et al*. 1979) or without rumen fluid Singh enzymes (Aufrere, 1982). Compared with other laboratory techniques, gas production has been proved to be accurate in predicting animal performance (Blummel and Ørskov, 1993, Khazaal *et al*. 1993a). While the gas production technique was slightly inferior to nylon bag technique in determining nutritive value of hays, it was suggested as being more efficient than the nylon bag for determining the nutritive value of feeds containing antinutritional factors (Khazaal *et al*., 1993b). The gas production techniques in combination with polyvinylpolyueriolidone (PVP) was reported to have a good potential for providing better insight into the effects of phenolic related antinutritive factors in biological systems (Khazaal *et al*., 1994). The gas technique differs from other *in vitro* technique by measuring evolution of gas as a result of fermentation.

Bogoro *et al*., (1999), measured gas production of sorghum stover at 3, 6, 12, 24, 48, 72 and 96 hrs and obtained 3.16, 5.50, 11.00, 19.40, 28.77, 33.43 and 37.20mls respectively. Ramachandra and Krishnamoorthy, (2000) also measured gas produced in 24hrs from untreated Ragi straw, 4 percent of urea treated Ragi

straw, 6 percent urea treated Ragi straw and concentrate mixture. They reported 39.15, 37.22, 28.43, and 36.99ml respectively. Khazaal *et al*., (1994) reported gas produced in 24 and 48hrs from 8 browse plants and found variations in the amount of gas produced. Gas produced ranged from 14.8 to 35.1ml in 24hrs and 20.60 to 38.70mls in 48hrs. The authors also reported strong relationship (R^2 = 0.84 : P<0.01) between the increase (%) in the gas produced and the change in total VFAs.

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

Valentine *et al*., (1999) concluded that differences in the conclusion drawn by different authors may be due to a number of factors such as the methodology used, the substrate and the type of animals used, the number of measurements and hence precision of description of the degradation curve and finally the mathematical model employed.

2.6 VOLATILE FATTY ACIDS

Volatile Fatty Acids (VFAs) are the main source of energy for ruminant animals. They are produced when feed materials are fermented in the rumen. They are similarly produced though in small amounts during the fermentation of feed residue in the large intestine (Ørskov and Ryle, 1990). It is now generally recognized that the main VFAs (acetic, propionic and butyric acids) are utilized with equal energetic efficiency (Ørskov and Ryle, 1990; Ørskov and Mclead 1990).

The finding that acetic acid is utilized as efficiently as other VFAs leaves unexplained the observation that roughages are utilized less efficiently than concentrates. However, as discussed by Ørskov and McLead (1990), the phenomenon can be explained by the chewing activities during eating, rumination and other activities associated with eating. Furthermore, if methane production is not measured, then it could be confused with a decrease in efficiency of utilization of VFAs (Ørskov, 1982).

It is well known that the proportion of acetic acid usually increases with increase cellulosic roughages in the diet while grain or starch usually ferment to yield a higher proportion of propionic acid. But the report of Ørskov, (1994) shows that the feeding of whole rather than rolled barley, wheat, oats and maize had a very large influence on the type of fermentation. It is therefore, not possible to predict alone from chemical composition of nutrients the type of fermentation to be expected. Ørskov, (1994) stated that the type of fermentation depends on

rumen environment especially pH and the degradation rate of the substrate. About 80% of the Volatile Fatty Acids produced in the rumen are absorbed through its wall, the surface area of which is greatly enlarged by numerous papillae. These papillae grow and regress in response to changes in food consumption and VFA concentration. The rest of the ruminal VFA is absorbed from the omasum and abomasum.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 COLLECTION AND PROCESSINGHH OF PIGEON PEA AND RICE STRAWS

3.1.1 Pigeon Pea (*Cajanus cajan*) Forage

The Pigeon Pea (*Cajanus cajan* (L) Millspaugh) used for this study was cultivated in May during the 2003 rainy season, at the Ahmadu Bello University, Zaria Students Field Practical Training Farm. Weather report of the year showed a rainfall of 31.0mm to 283.7mm between April and October. Temperature range was 23.0^{o}C to 24.7^{o}C. The land area was 1.5ha field, of well drained loamy soil. Land preparation involved ploughing and ridging. Pigeon pea seeds of light seed coat variety were planted in May at 25cm intra row and 35cm inter row spacing. A starter dose of N.P.K 15:15:15 was applied at 4 weeks at the rate of 50kg/ha. At 6 weeks, manual weeding was carried out and super phosphate fertilizer was applied at the rate of 50kg/ha. Second weeding was carried out at 9 weeks. The forage was harvested in September, 2003 at the flowering stage at about 30cm above the ground. It was left on the farm to wilt. After 4 days, the forage was collected and transferred to an airy room at the Departmental Animal Products Laboratory Unit. The forage was allowed to stay there until January 2004. In January 2004, the forage was moved to the National Animal Production Research Institute (NAPRI)

Shika and chopped Singh a chopper to a length of 30cm. This was then, stored in jute bags ready for the experiment.

3.1.2 **Rice straw**

The rice straw used was collected from a farm on the outskirts of Zaria metropolis. It was collected after the farmer had just harvested the rice. The rice was of a local variety (Badangama). The straw was also moved to the Animal Products Laboratory's airy room and allowed to remain there until January, 2004, when it was taken to the National Animal Production Research Institute (NAPRI) Shika. The straw was chopped to about 30cm length Singh a chopper and was then stored in jute bags until the commencement of the experiment. Agronomic practice of the rice crop, according to the farmer involved twice applications of N.P.K (20:10:10 and 15:15:15 respectively) at 50kg/ha at 4 weeks interval and twice manual weeding. The rice was paddy rice. A soil analysis of the rice farm was carried out to determine the exchangeable bases and soil particle size. The rice farm was divided into four equal parts and two samples were collected using agar to a depth of about 30cm from each of the parts. This was bulked and a sub-sample collected. The soil was analysed for exchangeable bases and particle size distribution according to Black (1965) and Bouyoucos (1951) respectively.

3.2 Experiments

3.2.1 Experiment I: Growth study

3.2.1.1 Determination of the chemical composition and mineral content of pigeon pea forage and rice straw

Representative samples of pigeon pea forage and rice straw were collected and chemically analysed to determine their dry matter, crude protein, crude fibre, ether extract and ash according to AOAC (1985). Cellulose, hemicelluloses, lignin, acid detergent fibre and neutral detergent fibre were determined by the method of Van Soest and Robertson (1988). Flame spectrophotometer was used to determine the content of calcium, phosphorus, sodium, iron, magnesium and potassium. Polyphenol was evaluated by the method of Reed *et al*., (1995) and gross energy was estimated by a Gallenkamp ballistic bomb calorimeter (AOAC, 1985).

3.2.1.2 Feeding trial

The objective of the study was to measure the response of Yankasa sheep fed rice straw supplemented with pigeon pea forage.

Animals, feeds and feeding:

Twenty female yearling Yankasa ewes were obtained from the flock raised at NAPRI Shika. Their average weight was 14.98kg-15.06kg body weight. The animals were dewormed with anthelmintics (Albendazole®) to control endoparasites and dipped in arcaricide solution (Ivomec®) to control ectopasites. They were also administered with Terramycine® long acting antibiotics a week

before the commencement of the adjustment period. The ewes were then transferred into individual feeding pens in the experimental unit of the Small Ruminant Research Programme of NAPRI, Shika.

The animals were blocked by weight and randomly assigned to the treatments, five animals per treatment. They were individually offered rice straw *ad libitum*. Animals in groups A to D were supplemented with pigeon pea forage at 0, 0.5, 1.0 and 1.5% of body weight respectively. The pigeon pea forage was offered at 08.00hr while the basal forage was offered an hour later. Rice straw and pigeon pea forage were offered separately. The rice straw was offered at about twenty percent in excess of the previous day's intake. The left over for each animal, was measured the following day before the day's feeding. The feeding trial had an initial 14 day adjustment period followed by 90days feeding trial during which measurements were taken.

The animals were weighed weekly using a hanging scale. The ewes were put into a 100kg bag and the weight taken. Pigeon pea forage offered was adjusted weekly to maintain pigeon pea forage inclusion at 0.0, 0.5, 1.0 and 1.5% of body weight. Quantities of feed offered and refused were weighed daily to determine feed intake. Fresh clean drinking water was offered daily *ad libitum*.

3.3 **Experiment II: Digestibility and nitrogen balance**

The aim of this study was to determine the digestibility of nutrients and nitrogen balance of different diets fed in the growth study.

Animals

Three animals were randomly selected from each treatment at the conclusion of the growth study. They were put in individual metabolism crates (49 x 20.5m) in a completely randomized design and fed their respective rations as in the previous study. An adjustment period of 10 days was allowed before the faecal and urine outputs were measured for the subsequent seven days. Total urine production was collected daily into a graduated plastic vessel containing 50ml of 50% HCL.

Feed intake was determined by finding the difference between the amount of feeds offered and the amount of feed refused. Samples of feed, feaces and urine were taken daily for the seven days. The daily faecal output was dried for initial determination of dry matter. A 5% aliquot of total urine output per day was removed each day and stored in a refrigerator (-4^0C). Faeces from each animal on each treatment were bulked thoroughly mixed and sub-sampled. Similarly the urine out put from each animal on each treatment were bulked, thoroughly mixed and a sub-sample taken.

Chemical Analysis

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

Statistical Analysis

Data obtained were subjected to analysis of variance using the General Linear Model (GLM) of SAS (1987) software package.

3.4 Experiment III: Rumen fermentation and blood metabolites

This study was carried out to determine rumen fermentation characteristics of diets containing 0, 0.5, 1.0 and 1.5% of body weight inclusion level of pigeon pea forage; ascertain the influence of treatments on pH; rate of fermentation; volatile fatty acid; blood urea; packed cell volume and other rumen metabolites. Their relationship and the extent to which nutrients were utilized were determined.

Animals

Sixteen yearling Yankasa ewes were used for this study. The ewes were kept in individual pens throughout the period of the study.

Design

Sixteen yearling Yankasa ewes were randomly assigned to four treatments in a completely randomized design. The treatment consisted of 0, 0.5, 1.0 and 1.5% of body weight inclusion of pigeon pea forage supplement. A basal diet of rice straw was fed *ad libitum*. Four ewes per treatment were kept in individual pens. The study lasted for 17 days consisting of 10 days adjustment period and seven days data collection of blood and rumen fluid.

3.4.1 Procedure for blood collection

Blood was sampled from the jugular vein with a hypodermic needle into vacutainer tubes on days 14 and 16 of the study at three, six, nine, twelve and

twenty-four hours after feeding. Blood samples were centrifuged immediately and plasma decanted into tubes and stored at -4^{0}C. Plasma urea nitrogen was determined (Archer and Robb, 1925).

3.4.2 **Procedure for rumen fluid sampling**

Rumen fluid was sampled on the 17th day. This was done with the aid of a stomach tube which was manually operated. The rumen fluid was sampled at three, six, nine, twelve and twenty-four hours after feeding. The fluid was immediately strained through cheese cloth and the pH was read with a digital pH meter. Rumen fluid samples were stored in plastic containers into which 3 drops of concentrated hydrochloric acid were added. These were stored at -4^{o}C and later analysed for ammonia-nitrogen, (Roy Markham, 1942) total volatile fatty acid (AOAC, 1980) and minerals.

Statistical Analysis

Data were subjected to analysis of variance procedure using GLM of SAS (SAS, 1987). Trend analysis was also carried out.

3.5 **Experiment IV:** ***In vitro*** **gas production**

This study was carried out to determine the nutritive value of pigeon pea forage using *in vitro* gas production technique and to ascertain the accuracy of gas production technique as a tool for predicting VFA and DM degradation in the rumen.

Design

A randomized complete block design was used. The treatments (0, 0.5, 1 and 1.5% of pigeon pea forage in the diet) was each replicated six times. Parallel syringes containing no substrate but rumen fluid served as blank.

Procedure

Feed samples were collected from the four treatments. This was determined from the result of the feeding trial in experiment I. This was ground to about 1mm and used for this study. About 200mg of the feed samples was placed into syringes lubricated with Vaseline®. The feed samples were incubated in triplicates on two different days, yielding six parallel measurements. The rumen liquor was obtained from the rumen with the aid of a rumen suction pump passed through two layers of cheesecloth into a warm flask of about 20ml volume filled with CO_2. Rumen liquor was taken before the morning feeding.

Thirty ml of the rumen liquor-medium – mixture was pipetted into each syringe pre-warmed to 39^{o}C and placed in an agitating incubator maintained at the same temperature. The gas produced was read through a calibrated pipette inverted over water, as the volume of the water displaced.

Readings of the gas produced was recorded at 3, 6, 12, 24 and 48hr. The syringes were gently shaken at each reading time. Real gas produced was obtained by subtracting the gas produced from the blank, from gas produced due to treatment effect.

Statistical Analysis

The data for gas production (mean of six duplicated runs) were fitted to the exponential equation.

Where

P = $a + b (1 – e^{-ct})$ of Ørskov and McDonald (1979)

P = gas production at time t,

(a + b) = the exponential gas production

a, b and c = constants in the exponential equation

3.6 **Experiment V**: **Rumen kinetics**

This study was carried out to determine the degradation characteristics of rice straw, pigeon pea forage and rice straw supplemented with 0.5, 1.0 and 1.5 percent of body weight pigeon pea at 3, 6, 9, 12, 24 and 36hrs post feeding. It was also to ascertain the rate of release of nitrogen in relation to ADF and NDF.

Procedure

Four grammes of rice straw, pigeon pea and the experimental diets, determined from the result of feeding trial were incubated in the rumen of fistulated rams. The fistulated rams were fed rice straw and pigeon forage. The feed samples were placed in nylon bags and secured to indigestible plastic rope by means of a rubber ring. The feed samples were securely tightened to the plastic rope and placed in the rumen through the rumen canula. Each sample was replicated four times. The feed samples were removed at the assigned hours and washed immediately under a running water for 15 minutes. They were then taken

to the laboratory for the determination of dry matter loss. After the determination of DM degradation the incubated samples were analyzed for ADF, NDF and nitrogen, according to Van Soest (1988) and Robertson and Khalili (1992) method of determining nitrogen. Washing losses was determined by washing the feed sample in running water for 15 minutes

Data Analysis

In the assessment of degradation of roughages, there is often an initial lag phase which gives rise to negative value for the DM degradation *in situ*, thus an alternative constant A, was used as recommended by Ørskov and Ryle (1990). A was defined as the initial washing loss, while the insoluble but fermentable matter was defined as B = (a + b) – A. C remains the rate of degradation of the insoluble DM fraction.

A correlation analysis between the volume of gas produced *in vitro* and DM degradation *in situ* over 24hours was carried out for the treatment diets, to determine the relationship between volume of gas produced *in vitro* and DM degradation *in situ*.

Regression analysis was also carried out between volume of gas produced *in vitro* and DM degradation *in situ* and VFA production *in vivo* over a period of 24 hours for the respective treatments.

Predictive equations were developed for the prediction of DM degradation and VFA production using the volume of gas produced *in vitro* as well as predictive equations for gas production and DM degradation over a period of 24 hours.

CHAPTER FOUR

4.0 RESULTS

4.1 EXPERIMENT I: Growth Study

4.1.1 Feed Content

The result of the soil analysis of the rice farm (Table 1) showed that the soil contained considerable amount of carbon, nitrogen and phospharus. The texture class of the soil is clay.

Table 2 shows the chemical, mineral and gross energy contents of rice straw and pigeon pea forage. The crude protein content of pigeon pea forage was higher than that of rice straw (15.75% compared to 10.81%), so also were the contents of ether extract, hemicelluloses and nitrogen free extract. The result also shows the presence of tannin (0.5mg/kg) in pigeon pea. The calcium content of pigeon pea (62.50ppm) was higher than that of rice straw (45.00ppm). The magnesium content were the same (10.50ppm). In the other minerals analysed (phosphorus, sodium, iron, potassium and sulphur) pigeon-pea forage had lower values compared to rice straw. Rice straw had higher neutral detergent fibre, cellulose, hemicelluloses and lignin than pigeon pea. It also has high content of silica (4.27%). Rice straw had gross energy content of 4431Kcal/kg which is lower than that of pigeon pea forage (4933kcal/kg).

Table 3 shows the mineral contents of the diets. While the content of calcium (Ca) increased as the inclusion level of pigeon pea forage increased from 0 to 1% of body weight, that of phosphorus (P) decreased (1.28 to 1.22ppm)

slightly as pigeon pea forage supplementation increased from 0 to 1.5% of body weight.

The contents of sodium (Na) and magnesium (Mg) are similar across the treatments. The contents of iron (Fe), potassium (K) and sulphur (S) did not show any definite pattern. They however, ranged from 0.10 to 0.12, 0.94 to 1.03 and 0.20 to 1.09 ppm for Fe, K and S, respectively.

4.1.2 **Feed Intake of Ewes Fed the Experimental diets**

Table 4 shows the feed intake, nutrient intake and growth rate of Yankasa ewes fed the experimental diets. The result shows a decline in the voluntary intake of rice straw (534.89-417.72g/day) as the supplementation level of pigeon pea forage increased from 0 to 1.5% of body weight. This decrease was however, only significant ($P<0.05$) at 1.5% of body weight supplementation. The voluntary intake of pigeon pea forage however, increased (63.54, 116.22 and 131.87) as the inclusion level of the forage increased from 0.5, 1.0 to 1.5% of body weight, respectively with 0.5% pigeon pea forage inclusion level being significantly ($P<0.05$) lower than 1.0 and 1.5% of body weight supplementation.

In terms of total feed intake, there is a general increase in feed intake as a result of pigeon pea forage supplementation. The pattern showed a significantly higher ($P<0.05$) intake at 1.0% of body weight supplementation. Supplementation at 1.5% of body weight, significantly

Table 1: Exchangeable bases in mcg/100g and particle size distribution of soil obtained from the rice farm

Ca	Mg	K	Na	H+Al	CEC	C%	N%	P ppm
3.80	1.65	0.29	2.60	0.60	12.60	0.82	0.07	7.50
		Particle size distribution corrected to 20^{o}c						
% clay	% silt	% sand	Texture class					
43	25	32	Clay					

Table 2: Chemical composition (%) and energy content of rice straw and pigeon pea forage

Feed ingredient	Nutrient													
	DM	CP	CF	EE	Ash	NFE	ADF	NDF	CELL	HEMI	LIG	SI	GE (Kcal/kg)	Tannin (mg/kg)
Rice straw	96.31	10.81	28.42	3.81	15.17	41.79	45.81	68.43	38.72	23.35	5.11	4.27	4431	-
Pigeon pea	92.05	15.75	29.00	5.37	5.87	44.01	37.04	59.71	23.35	38.35	3.63	-	4933	0.5

	Mineral (ppm)						
	Ca	P	Na	Mg	Fe	K	S
Rice straw	45.00	23.87	4.55	10.50	2.25	18.75	15.63
Pigeon pea	62.50	17.05	2.31	10.50	1.75	12.22	11.72

Table 3: Mineral content (ppm) of diets

Element	Pigeon pea forage Levels (% of body weight)			
	0.0	0.5	1.0	1.5
Calcium	2.41	2.60	2.87	2.88
Phosphorus	1.28	1.28	1.33	1.22
Sodium	0.24	0.24	0.25	0.22
Magnesium	0.56	0.58	0.62	0.58
Iron	0.12	0.12	0.10	0.12
Potassium	1.00	0.20	1.03	0.94
Sulphur	0.84	0.20	1.09	0.94

Table 4: Feed intake and the performance characteristics of Yankasa ewes fed rice straw supplemented with pigeon pea forage.

Feed/Nutrient intake (g/day)	Pigeon Pea levels (% of body weight)					
	0.0	0.5	1.0	1.5	SEM	Sig
Rice straw intake	534.89[a]	489.60[ab]	475.34[ab]	417.72[b]	37.9	*
Pigeon pea intake	-	63.54[b]	116.22[ab]	131.87[a]	32.9	*
Total feed intake	534.89[b]	553.14[ab]	591.56[a]	549.59[b]	19.8	*
CP intake	53.49[b]	58.97[a]	65.83[a]	62.54[a]	4.6	*
NDF intake	366.03[b]	372.92[ab]	394.62[a]	364.59[b]	11.6	*
ADF intake	245.03[ab]	247.81[ab]	260.76[a]	240.16[b]	7.1	*
Hemicelluloses	159.45[b]	162.93[b]	177.28[a]	164.78[ab]	6.4	*
Cellulose	207.11[a]	203.51[a]	211.19[a]	192.53[b]	6.4	*
Silica intake	22.84[a]	20.91[a]	20.30[a]	17.84[b]	1.6	*
Tannin (mg/kg)	-	31.77[b]	58.11[ab]	65.94[a]	16.5	*
Metabolisable energy (Kcal/kg)	2382.6[a]	2584.3[a]	2813.0[a]	1038.96[b]	655.7	*
Initial weight (Kg)	15.06	15.04	14.98	15.06	0.02	NS
Final weight (Kg)	13.05[b]	13.43[b]	16.23[a]	16.12[a]	1.7	*
ADG(g/day)	-22.34[b]	-17.89[b]	13.89[a]	11.78[a]	8.33	*
Feed efficiency	-266.11[b]	-343.57[b]	473.25[a]	518.48[a]	177.83	*

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

* Significant at $P<0.05$

NS Not significant at $p<0.05$

(P<0.05) decreased total feed intake. Total feed intake at 0.0% and 1.5% body weight supplementation of pigeon pea forage were however, similar.

The result also indicate a significant (P<0.05) difference in crude protein intake due to supplementation with pigeon pea forage. Even though crude protein intake increased from 58.97g/day to 65.83g/day for 0.5 and 1.0% supplementation levels, this increase was not significant. The result showed a non-significant decline in crude protein intake at 1.5% of body weight of pigeon pea supplementation. This pattern is similar to results obtained for the intakes of neutral detergent fibre (NDF), acid detergent fibre (ADF), hemicelluloses and cellulose. In these results, the intake values were significantly (P<0.05) higher at 1.0% of body weight supplementation.

The intake of silica was highest at 0.0% supplementation level. This declined at 0.5 and 1.0% of body weight to 20.91 and 20.30g/day, respectively. This decline was however, not significant. The significant decline in silica intake (17.84) occurred only at 1.5% of body weight. The intake of tannin increased significantly (P<0.05) from 31.77mg/kg at 0.5% pigeon pea forage supplementation to 58.11 and 65.94mg/kg at 1.0 and 1.5% supplementation levels respectively. The increase in tannin intake between 1.0 and 1.5% of body weight pigeon pea forage supplementation was however, not significant (P>0.05).

4.1.3 **Performance of Yankasa ewes fed experimental diets.**

Table 4 also shows the result of the performance of Yankasa ewes fed the experimental diets. The results showed a decline in weight in ewes fed rice straw only (0.0%) and rice straw supplemented with 0.5% of body weight pigeon pea forage. Ewes on 0.0% pigeon pea supplementation lost 2.01kg while those on 0.5% lost 1.61kg within the experimental period. The loss in weight between these treatments was however not significant (P>0.05).

Pigeon pea forage supplementation at 1.0 and 1.5% of body weight resulted in weight gain. Ewes on 1.0% pigeon pea forage supplement gained 1.25kg while those at 1.5% gained 1.06kg at the end of the study period. This was equal to a daily weight loss of 0.022 and 0.018kg for 0.0, 0.5, and gain of 0.014 and 0.012kg for 1.0 and 1.5% of body weight pigeon pea forage supplementation, respectively.

A non significant feed efficiency ratio of 473.25 and 518.48 were obtained at 1.0 and 1.5% supplementation levels respectively, while ewes on 0 and 0.5% pigeon pea forage lost weight. The feed efficiency obtained at the level of 1.0 and 1.5% of body weight supplementation were very low and not significantly different.

4.2 EXPERIMENT II: Nutrient digestibility and nitrogen retention study

The results of nutrient digestibility and nitrogen retention studies of ewes are presented in Table 5. The result showed a high (88.82 – 90.06) percentage of nitrogen retention across the treatment diets. There were however no significant (P>0.05) differences among the treatments. Percent DM digestibility increased in the supplemented treatment (16.09, 33.47 and 23.88) when compared to the

control (13.06). The percent DM digestibility was however, not significantly ($P>0.05$) different between 0.0 and 0.5% of body weight pigeon pea forage supplementation. A significantly ($P<0.05$) higher percent DM digestion was reported for 1.0 and 1.5 pigeon pea forage supplementation than for the lower two levels.

The percent organic matter digestibility (OMD) was significantly ($P<0.05$) low in the rice straw only diet. Supplementation of pigeon pea forage at 0.5% body weight improved percent OM digestibility significantly ($P<0.05$). Further increase in supplementation level to 1.0% also resulted in a corresponding increase in percent OM digestibility to 42.62. Pigeon supplementation at both 1.0 and 1.5% of body weight resulted in higher ($P<0.05$) OM digestibility over the control. Percent NDF digestibility was significantly ($P<0.05$) high at 1.0% pigeon pea forage supplementation. This was followed by NDF digestibility at 1.5 and 0.0% Supplementation. The NDF digestibility values between 0.0 and 0.5% supplement were similar and significantly ($P<0.05$) lower than the result (20.53%) obtained at 1.5% of body weight supplementation.

The result of ADF digestibility also shows no significant ($P>0.05$) improvement in the digestibility of ADF as the percent inclusion level of pigeon pea forage increased from 0.0 to 0.5%, of body weight inclusion (2.38 and 4.63, respectively). It however, increased significantly ($P<0.05$) to 28.04 at 1.0% and decreased significantly to 15.73 at 1.5% of body weight supplementation.

The percent digestibility of hemicelluloses did not follow any definite pattern and are similar across the treatments. It was however highest at 1.0% of body weight supplementation

Table 5: Nutrient digestibility (%) and nitrogen retention of ewes fed rice straw supplemented with pigeon pea (pp) forage

Parameter	PP inclusion in diet (% of body weight)					
	00	0.5	1.0	1.5	SEM	Sig
Total DM intake (g/day)	288.43	313.27	365.41	399.30	58.43	NS
% N retained	89.83	88.82	90.06	86.19	2.77	NS
DM digestibility (%)	13.05^{c}	16.09^{c}	33.47^{a}	23.88^{b}	2.28	*
OM digestibility (%)	24.21^{c}	28.12^{c}	42.62^{a}	33.00^{b}	1.89	*
NDF digestibility (%)	13.71^{c}	12.11^{c}	33.85^{a}	20.53^{b}	2.45	*
ADF digestibility (%)	2.38^{c}	4.63^{c}	28.04^{a}	15.73^{b}	2.35	*
Hemicelluloses digestibility (%)	37.25^{b}	32.81^{b}	50.24^{a}	35.2^{b}	10.05	*

^{a,b,c} Means on the same row with different superscripts are significantly (P<0.05) different.

* Significant at P<0.05

NS Not significant.

4.3 EXPERIMENT III: Rumen and blood metabolites study

4.3.1 Rumen metabolites

Table 6 shows the results of rumen ammonia nitrogen (NH_3-N) in ewes fed the experimental diets. The highest level of NH_3-N in the diet with rice straw only was obtained at 6 and 9 hours post-feeding. These values were similar but they were significantly ($P<0.05$) higher than the results reported for the other sampling times. Twelve and 3 hours had lower NH_3-N levels which were significantly ($P<0.05$) different from each other. The least (1.16mg/l) NH_3 level in this treatment was obtained at 24 hours post feeding.

Supplementation of pigeon pea forage to a basal rice straw diet at 0.5% of body weight generally increased the levels of NH_3-N across all the sampling times. Six and 12 hours post-feeding samplings had the highest (8.38 and 8.57mg/l NH_3-N). At 9 hours, there was a significant ($P<0.05$) decline in NH_3-N. This level (6.19) is similar to what was obtained at 3 hours (6.09mg/l). They are however, significantly ($P<0.05$) higher than 2.86mg/l NH_3-N concentration obtained at 24 hours post feeding.

There was a further increase across all sampling hours when pigeon pea forage supplementation increased to 1.0% of body weight. There was however no significant difference in the concentration of NH_3-N across the sampling time. This non-significant pattern was also the trend when the pigeon pea forage was increased to 1.5% of body weight. This treatment however, showed a decline in the NH_3-N concentration when compared to 1.0% of body weight pigeon pea

supplementation. The result of NH_3-N concentrations showed some fluctuations in the 0.0 and 0.5% pigeon pea forage supplementation. When the level of pigeon pea forage offered increased beyond these to 1.0 and 1.5% levels, the NH_3-N approached a relatively constant concentration within the treatments.

Table 7 shows the rumen volatile fatty acids (VFA) concentration of the ewes fed pigeon pea supplemented with rice straw. In the diet with rice straw only the highest VFA (26.33) level was obtained 9 hours posts-feeding. This was significantly ($P<0.05$) higher than VFA value obtained at 12 hours post feeding. At 3 and 6 hours post feeding, the values were 19.00 and 18.17mm/l respectively. These values though similar were significantly ($P<0.05$) higher than the VFA value reported at 24 hours post-feeding.

At 0.5% of body weight pigeon pea forage supplementation there was a general increase in the level of VFA across all sampling hours. The peak was however still obtained at 9 hours post feeding. This value (43.38mm/l) was significantly ($P<0.05$) higher than VFA values obtained at 6 and 12 hours post feeding which were similar. The least concentration of VFA (17.50mm/l) was reported at 24 hours post feeding.

Table 6 Effect of level of pigeon pea supplementation and time of sampling on rumen NH_3-N concentration (mg/l) of ewes fed rice straw.

PP inclusion level (% of body weight)	NH_3-N hours after feeding (mg/l)						
	3	6	9	12	24	SEM	Sig
0.0	2.73[c]	3.81[a]	3.81[a]	3.14[b]	1.16[d]	0.15	*
0.5	6.09[b]	8.38[a]	6.19[b]	8.57[a]	2.86[c]	0.63	*
1.0	8.66	7.05	7.43	10.38	4.48	6.69	NS
1.5	7.33	8.00	5.33	8.00	3.67	5.53	NS

[A,b,c] Means in the same row bearing different superscripts are significantly ($P<0.05$) different.

* Significant at $P<0.05$

NS Not significant at $P<0.05$

Table 7: Effect of level of pigeon pea supplementation and time of sampling on rumen VFA concentrations (mm/100ml) of ewes fed rice straw.

PP inclusion level (% of body weight)	VFA (mm/100ml) Hours after feeding						
	3	6	9	12	24	SEM	Sig
0.0	19.00[c]	18.17[c]	26.33[a]	22.83[b]	13.00[d]	1.35	*
0.5	29.33[b]	34.00[b]	43.38[a]	32.46[b]	17.50[c]	1.89	*
1.0	36.00	35.67	43.33	37.17	30.67	6.25	NS
1.5	35.05	43.67	40.33	31.67	29.33	5.48	NS

[A,b,c] Means in the same row bearing different superscripts are significantly (P<0.05) different.

* Significant at P<0.05

NS Not significant at P<0.05

The general increase in VFA production continued at 1.0% of body weight pigeon pea supplementation where VFA production peaked at 9 hours with a value of 43.33mm/l. This is similar to peak VFA produced at 9 hours also in the 0.5% of body weight pigeon pea supplementation. This treatment however, did not result in any significant difference in VFA production across sampling time. This trend was also presented in the ewes offered 1.5% of body weight pigeon pea forage. The result in this treatment showed a decrease in VFA produced in all but 6 hours post feeding sampling time.

The result of the pH of rumen fluid measured from ewes fed the experimental diets is presented in Table 8. The pH remained similar for 3 to 12 hours post feeding for 0.0 and 0.5% body weight pigeon pea forage supplementation. At 24 hours post-feeding however, there was a significant ($P<0.05$) rise in pH. (6.88 in 0.0% and 7.10 in 0.5% treatment). Ewes offered 1.0 and 1.5% body weight pigeon pea showed significant ($P<0.05$) differences in pH across sampling hours. In 1.0% of pigeon pea treatment, the pH at 3 and 24 hours post-feeding were similar and significantly ($P<0.05$) higher than the pH obtained at other sampling hours. This was followed by the pH obtained at 9 hours post-feeding pH taken at 6 and 12 hours post-feeding were the least and they were similar.

This pattern was different from pH values obtained in 1.5% of body weight pigeon pea treatment. In this treatment, 24 hours posts-feeding had a

Table 8**:** Effect of level of pigeon pea forage supplementation and time of sampling on pH of rumen fluid of ewes fed rice straw.

PP inclusion levels (% of body weight)	pH hours after feeding						
	3	6	9	12	24	SEM	Sig
0.0	6.54^{b}	6.57^{b}	6.63^{b}	6.52^{b}	6.88^{a}	0.03	*
0.5	6.76^{b}	6.75^{b}	6.68^{b}	6.58^{b}	7.10^{a}	0.07	*
1.0	6.55^{a}	6.37^{c}	6.46^{b}	6.36^{c}	7.20^{a}	0.04	*
1.5	6.69^{b}	6.78^{b}	6.54^{c}	6.74^{b}	7.31^{a}	0.05	*

^{A,b,c} Means in the same row bearing different superscripts are significantly ($P<0.05$) different.

* Significant at $P<0.05$

significantly ($P<0.05$) higher pH than the others. While the pH at 3, 6 and 12 hours were comparable to each other and significantly ($P<0.05$) higher than the pH at 9 hours post feeding.

Results of the mean rumen metabolites and pH measured in this study are presented in Table 9. The pH increased significantly ($P<0.05$) in treatments 0.5 and 1.5% of body weight pigeon pea forage offered. This treatment had comparable pH values. Zero and 1.0% pigeon pea treatments had significantly ($P<0.05$) lower but similar pH values.

The mean values for NH_3-N across the treatments showed that 0.0% of body weight pigeon pea forage had the least NH_3-Nmg/l level. This was significantly ($P<0.05$) lower than the other treatments. Ewes fed 0.5, 1.0 and 1.5% of body weight pigeon pea forage had comparable NH_3-N/mg/l levels which were significantly ($P<0.05$) higher than the 0.0% body weight treatment. The result showed increase in the NH_3-N concentration, as the level of pigeon pea forage supplementation increased from 0.0 to 1.0%. When pigeon pea forage supplementation increased to 1.5% of body weight there was a drop in NH_3-N even though this decline was not significant.

The effect of the treatments on mean VFA is also presented in Table 9. Volatile fatty acid was least (19.87mm/l) when rice straw was not supplemented. Supplementation with pigeon pea forage at 0.5, improved

Table 9: Effect of pigeon pea forage supplementation on mean rumen fluid variables in ewes fed rice straw.

Variables	PP inclusion levels (% of body weight)					
	0.0	0.5	1.0	1.5	SEM	Sig
pH	6.63^{b}	6.79^{a}	6.59^{b}	6.87^{a}	0.03	*
NH_3-Nmg/l	2.93^{b}	6.42^{a}	7.60^{a}	6.47^{a}	0.26	*
VFA mm/100ml	19.87^{c}	31.33^{b}	36.57^{a}	36.0^{a}	0.81	*

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

* Significant at $P<0.05$

significantly ($P<0.05$) the VFA level. This was further increased significantly ($P<0.05$) at the 1.0% supplementation level. Further pigeon pea increase to 1.5% of body weight resulted in a non significant decrease in the VFA level.

4.3.4 **Mineral levels in rumen fluid**.

The mean mineral levels in the rumen fluid of ewes fed the experimental diet is presented in Table 10. The result showed that there were no significant ($P>0.05$) differences among the treatments in the levels of Ca, P, Na and Fe. There were however, significant ($P<0.05$) variations in the amounts of Mg and K in the rumen fluid. The result indicated that 1.0% of body weight pigeon pea forage supplementation had a significantly higher Mg level. The Mg levels in the other treatments were similar. In the case of K however, it was the 0.5% pigeon pea forage supplementation that had the highest K level. This was however not ($P>0.05$) significantly different from 1.0 and 1.5% body weight supplementation.

Table 10: Mineral content in the rumen fluid of ewes fed rice straw supplemented with pigeon pea forage.

Mineral (PPM)	Level of pigeon pea forage supplement (% of body weight)					
	0.0	0.5	1.0	1.5	SEM	Sig
Calcium	20.66	24.11	22.27	21.66	3.75	NS
Phosphorous	2.51	2.85	2.86	2.56	0.45	NS
Magnesium	48.32 [b]	48.96 [b]	54.53 [a]	47.74 [b]	1.16	*
Sodium	19.18	18.49	15.99	19.58	4.01	NS
Potassium	21.66 [b]	30.77 [a]	24.41 [ab]	28.92 [ab]	1.24	*
Iron	25.41	24.80	21.00	22.40	4.73	NS

a. b Means in the same row bearing different superscripts are significantly ($P<0.05$) different

* Significant at $P<0.05$

NS Not significant at $P<0.05$

4.3.2 **Blood Metabolites**

Table 11 shows the results of plasma urea nitrogen levels in ewes fed the experimental diets. In ewes fed rice straw only, there were no significant differences in the levels of plasma urea nitrogen (PUN) within the 24 hours sampling period. The highest level (3.20) was however recorded at 6 hours post feeding while the least level (2.00) was obtained at 24 hours post feeding. When pigeon pea forage was offered at 0.5% of body weight, there was a general increase in the level of PUN at all the sampling hours. Six hours post feeding had a significantly ($P<0.05$) higher PUN. The level of PUN obtained at 3 and 9 hours post-feeding were similar and significantly higher than levels obtained at 12 and 24 hours.

At 1.0% of body weight pigeon pea forage supplementation there was a corresponding increase in the PUN levels when compared to either 0.0 or 0.5% supplementation levels. In this treatment also PUN level at 6 hours post-feeding gave significantly ($P<0.05$) higher values. Plasma urea nitrogen levels at 3 and 9 hours post-feeding were significantly ($P<0.05$) different in this treatment with PUN value at 3 hours being higher than the PUN value obtained at 9 hours. Even though the PUN level obtained at 12 hours post-feeding was higher than that obtained at 24 hours post-feeding, there was no significant difference between them.

Table 11: Effect of level of pigeon pea forage supplementation and time of sampling on plasma urea nitrogen (PUN) (mm/l) concentration of ewes fed rice straw

PP inclusion level % of body weight	PUN content hours after feeding (mm/l)						
	3	6	9	12	24	SEM	Sig
0.0	2.60	3.20	2.50	2.30	2.00	1.21	NS
0.5	4.30 [b]	5.90 [a]	4.20 [b]	3.40 [c]	2.33[d]	0.24	*
1.0	5.57[b]	6.37[a]	4.87[c]	4.17[d]	3.73[d]	0.26	*
1.5	5.13 [a]	5.60 [a]	4.60 [b]	3.00 [c]	2.60[c]	0.28	*

[a,b,c,d] Means in the same column bearing different superscripts are significantly ($P<0.05$) different.

* Significant at $P<0.05$

NS Not significant at $P<0.05$

At 1.5% of body weight pigeon pea forage supplementation there was a general decrease in the levels of PUN across all sampling time when compared to 1.0% of body weight supplementation levels at 3 and 6 hours post feeding were similar but significantly ($P<0.05$) higher than levels obtained at all the other sampling times.

4.3.3 **Mean blood variables**

The results of the mean blood variables are presented in Table 12. The result showed that the percentage of packed cell volume (PCV) increased from 21.00 in the unsupplemented diet to 32.00 at 1.0 percent supplementation. There was no significant difference ($P>0.05$) in the PCV levels of 0.5, 1.0 and 1.5% body weight supplementation. Haemoglobin level also followed the same pattern with the highest level of 73.00 percent at 1.0 and least (48.00) at 0.0% supplementation. There was no significant ($P>0.05$) difference in the level of white blood cells (WBC) among the treatments. The unsupplemented animals however, had the highest WBC of 5.43×10^9/l.

There were significant ($P<0.05$) differences in the mean levels of plasma urea nitrogen (PUN) across the treatments. The unsupplemented rice straw had the least PUN of 2.52ppm while 0.5 and 1.5% body weight supplementation were similar and significantly ($P<0.05$) lower than the PUN value obtained at 1.0% supplementation.

4.4 Rumen Degradation

Fig. 1 shows the DM degradation of the feed ingredients used in this study. There was poor degradability of rice straw compared to pigeon pea forage. A linear relationship exist between hours of incubation and DM degradation.

The result of the rumen degradation study is presented in Table 13. The result showed increase in DM degradation of the various treatment diets over a period of 36 hours. Three hours incubation period had the least DM degradation while 36 hours incubation period had the highest DM degradation within each treatment diet.

Comparing DM degradation of the various treatment diets within a given time, showed that there was an increase in DM degradation as the percent inclusion of pigeon pea increased from 0.0% to 1.0% of body weight across all incubation hours. When the percent inclusion of pigeon pea increased to 1.5% of body weight, there was a decline in DM degradation across all incubation period. The major part of DM losses from nylon bags occurred between 12 and 36 hours of incubation for all the treatment diets.

Table 12. Effect of level of pigeon pea supplementation on mean blood parameters in ewes fed rice straw.

Parameter	Pigeon pea forage inclusion in diets (% of body weight)					
	0.0	0.5	1.0	1.5	SEM	Sig
PCV (%)	21.00[b]	28.33[ab]	32.00[a]	30.33[a]	4.84	*
Haemoglobin (%)	48.00[b]	64.00[ab]	73.00[a]	68.11[ab]	10.81	*
WBC X 10^9/l	5.43	5.00	4.40	4.33	2.12	NS
Plasma urea-N* (mm/l)	2.52[c]	4.03[b]	4.94[a]	4.19[b]	0.10	*

[a, b, c] Means on the same row bearing different superscripts are significantly ($P<0.05$) different *($P<0.01$)

* Significant at $P<0.05$

NS Not significant at $P<0.05$

Table 13:Effect of level of pigeon pea supplementation on dry matter degradation (g/kg)

Treatments (% of body weight inclusion of pigeon pea forage).	DM degradation (h)									
	3	6	9	12	24	36	a	b	a + b	c
0.0	57.50	63.50	68.00	67.00	102.50	118.25	10.79	118.25	129.04	0.0141
0.5	104.00	109.00	120.25	122.75	148.75	190.75	18.68	190.75	209.43	0.0192
1.0	131.75	182.50	185.25	190.50	223.50	250.25	57.89	250.25	309.14	0.0214
1.5	81.00	93.50	112.75	133.50	163.75	172.50	72.17	172.50	244.67	0.0195
Mean	93.56	112.13	121.56	128.44	159.63	182.94	39.88	182.94	223.07	
SEM	31.76	50.58	45.81	50.61	49.93	54.42	29.79	53.66	75.06	

A - Washing loss (water soluble fraction)
B - The insoluble but fermentable matter.
a, b and c - Constants in the exponential equation $p = a + b (1 - e^{ct})$.
c - Rate of Dm degradation.

There was significant difference ($P<0.05$) in the degradation characteristics among the diets. The DM degradation rate constant varied significantly from 0.014 to 0.02 per hour. The a value ranged from 10.79 to 72.17g/kg DM. Potential degradability was highest (309.14g/kg) at 1.5% of body weight pigeon pea inclusion and least (129.04g/kg) at the unsupplemented rice straw diet. Figures 2, 3 and 4 show the DM degradation of *in sacco* incubated feed samples and the quadratic regression equations generated from the degradation data over the incubation periods. The R^2 values were high and ranged from $R^2 = 0.8639$ at 0.0% pigeon pea supplementation to 0.9527, 0.8680 and 0.9994 at 0.5, 1.0 and 1.5% supplementation respectively.

The regression analysis between potential DM degradation (a + b) and daily DM intake and apparent DM digestibility were high with R^2 values of 0.88 and 0.73 respectively. The R^2 value for potential DM degradation and daily weight gain was $R^2 = 0.77$. These relationships are presented in figures 5, 6 and 7.

Gas Production Study

The result of the gas production study is presented in Table 14. The table showed the volume of gas produced and the degradation characteristics obtained by fitting the data of gas production to the exponential equation $P = a + b (l – e^{ct})$.

There was an increase in cumulative gas production as the incubation time increased from 3 to 48hours for all the treatment diets (figure 8). The total amount of gas produced for each reading time increased as the level of pigeon pea forage supplementation increased from 0.0% (rice straw) to 1.0% of body weight. Increase in pigeon pea forage supplementation to 1.5% of body weight resulted in a decline in gas production.

The result showed significant differences ($P<0.01$) in the amount of gas produced at 48hours incubation within the treatments with 1.0% of body weight supplementation being significantly ($P<0.01$) higher than all the others and rice straw only being the least. The pattern of gas production for the treatment diets is presented in Fig. 8. The figure showed increase in the rate of production from 3-24hrs after which the rate appeared to decline.

The fermentation characteristics (a + b) representing the total amount of gas produced from the exponential equation $P = a + b (l – e^{ct})$ showed that 1.0% of body weight pigeon pea forage supplementation had the highest gas production. This was followed by 1.5% and 0.5% and the least was rice straw only. The rate of gas production represented by c is also shown.

Table 14: Cumulative gas production *in vitro* (ml/200mg DM) of ewes fed rice straw supplemented with pigeon pea forage.

Treatments (pigeon pea % of body weight supplementation)	Gas Produced (Hours)									
	3	6	9	12	24	48	a	b	a + b	c
0.0	10.20	10.72	12.82	15.02	22.55	23.67	10.39	23.67	34.06	0.320
0.5	13.65	18.77	21.90	26.63	35.85	37.32	17.26	37.32	54.26	0.495
1.0	14.93	20.38	23.58	28.65	38.17	39.17	18.77	39.17	57.94	0.517
1.5	14.53	19.97	22.07	24.47	31.92	33.23	17.98	33.23	51.21	0.375
Mean	13.33	17.46	20.09	23.69	32.12	33.48	16.10	33.35	49.37	
SEM	2.15	4.54	4.91	6.03	6.88	6.91	3.86	6.91	10.58	

a, b and c = are constants in the exponential equation $P = a + b (l – e^{ct})$.

a + b = potential gas production. c = rate of gas produced

The curve of gas production *in vitro* at 3, 6, 9, 12 and 24hrs and the regression equation of gas production against duration of fermentation are presented in figures 9, 10, 11 and 12, for 0.0, 0.5, 1.0 and 1.5% of body weight pigeon pea forage supplementation respectively. The results showed strong R^2 values for all the treatment diets. The R^2 values range from 0.9855 for 1.0% supplementation to 0.9566 for 1.5% of body weight supplementation.

The regression of potential gas production (a + b) values and DM intake for the various treatments was not significant (R^2 = 0.61). Similar results were obtained for potential gas production and apparent DM digestibility (R^2 0.53), and potential gas production and daily weight gain (R^2 = 0.43). These relationships are presented in figures 13, 14 and 15.

4.6 Correlation of gas production and DM degradation.

Table 15: Relationship between gas produced and DM degradation of rice straw supplemented with pigeon pea forage.

Pigeon pea inclusion (% of body weight)	Gas Produced (ml)	DM Degradation (g)	R
0.0	15.83 [d]	79 [c]	0.86**
0.5	25.69 [b]	133 [b]	0.69**
0.1	27.57 [a]	194 [a]	0.62**
1.5	24.36 [c]	126 [b]	0.88**
SEM	0.23	3.4	

a, b, c, d Means in the same column bearing different superscript are significantly different ($P<0.05$),

**($P<0.01$)

Result of correlation of gas production *in vitro* and DM degradation. *In sacco* (Table 15) shows positive relationship between gas production and DM degradation. One percent supplementation level had the least R value of 0.62 while 1.5% had the highest R value (0.88).

The table also showed that there were significant ($P<0.05$) differences in the amounts of gas produced between the treatments. The highest volume of gas produced. (27.57ml) was obtained at 1.0% of body weight supplementation followed by 0.5% supplementation. The least (15.83) was recorded for the unsupplemented diet. The DM degradation was also significantly ($P<0.05$) higher at the 1.0% supplementation but 0.5 and 1.5% of body weight supplementation were similar. They were however, significantly ($P<0.05$) higher than the DM obtained at the supplemented diet.

The regression of gas production against DM degradation and volatile fatty acid production for all the treatment diets are presented in figures 16a, b, c and d and 17a, b, c and d, respectively. The results showed high R^2 values for the regression of gas production against DM degradation ranging from 0.86 in the unsupplemented rice straw to 0.99 at 1.5% of body weight pigeon pea forage supplementation.

Similar though lower values were obtained for the regression of gas production against volatile fatty acid production where the R^2 values were 0.67, 0.90, 0.69 and 0.76 for 0.0, 0.5, 1.0 and 1.5% pigeon pea forage supplementation respectively.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Feeding Trial

5.1.1 Physical appearance of the feed ingredients.

Rice straw was bulky. Pigeon pea forage was steamy and like other leguminous forages had the problem of leaf shattering. The cutting of both forages to about 30cm helped to reduce the bulkiness and prevent selection of the leafy parts of pigeon pea forage. It also presented a more homogenous mixture of leaf and stem. The woody nature of pigeon pea forage had been reported by Whitman and Norton (1981). They reported that the actual yield on edible forage is about 50% of the total forage produced. Faris and Singh (1999) also stated that pigeon pea stem serves as important household fuel and could be used for field fence, buts and baskets. They further stated that given the increase Singh shortage of fuel wood in villages, pigeon pea sticks are likely to be in demand and many small holder farmers are likely to grow it.

5.1.2 Proximate and energy content of feed ingredients.

The crude protein content of the rice straw used in this study (10.81%) was higher than that of rice straw reported by Anshu *et al* (1997) and Jian-xin *et al* (2001). They reported a range of 4.6 – 7.3% for eight varieties of rice straw.

The acid detergent and neutral detergent fibre contents obtained were similar to values of 49.2 – 56.00% ADF and 66.5 – 77.6% NDF reported by Mosi and Butterworth (1985) and Dutta *et al*. (1999). Similar results were also obtained for hemicelluloses 18 – 23% (Zhiliang *et al*., 1996) cellulose 34.5 percent (Dutta *et al* 1999) and gross energy 15.9MJ/Kg DM (Cann *et al*., 1993).

The ash content (15.17%) is also similar to values of 16.6 and 18.6 percent reported for Philippines and California varieties of rice straw (Balista *et al*, 1989

and Rahal *et al*., 1997). Ahoefa *et al* (2001) obtained variable ash content from fifteen varieties of rice straw. He reported a range of 9.6 to 17.1 percent.

Silica content of 4.27% is slightly below the range of 5-16% reported by Bae (1997). Vadiveloo and Phang (1996) explained that process Singh methods particularly during collection of the straw is a major determinant. Sand contributes to the silica content of the straw. Vadiviloo (1992) also stated that silica uptake from soil and content in plant depends on its concentration in soil solution and its deposition varies among rice varieties.

In general, farmers grow different cultivars of rice. This affects the nutrient composition of the straw. Doyle and Oosing (1994) attributed these differences in nutrient composition to genetic factors as well as management practices during growth and harvest. In this study, the CP content of rice straw was higher than what had been reported in literature. (Jian-Xian *et al*., 2001) This could be because the straw contained some amounts of rice which were either not matured or were left behind as a result of inefficient process Singh method. The soil analysis also showed considerable amount of nitrogen which could have contributed to the high crude protein content in the rice plant hence the straw.

5.1.3 **Mineral content of feed ingredients**

Calcium was higher in pigeon pea forage than in rice straw. This is generally true for most legumes. The ratio of 1.2:1 which is recommended as optimum for efficient performance (Kearl 1982), is obtained in both rice straw and pigeon pea forage. Ogundipe (2005) stated that ruminants can tolerate wider range of 1:1 to 7:1.

Levels of sodium, magnesium, iron, potassium and sulphur observed in this study were within the range reported for dry roughages (Kearl,1982). Levels of calcium, phosphours, magnesium, sodium, potassium and iron obtained in this study were similar to the report of Mosi and Butterworth (1995) who fed *teff* straw alone or supplemented with various of either *sesbania* or *Leucaena*

5.1.4 **Tannin in pigeon pea forage**

Tannin content of the pigeon pea forage, used in this study was low. Singh (1988) reported that pigeon pea contains considerable amounts of polyphenolic compounds. He however stated that the content of tannins were much higher in pigeon pea cultivars with dark seed coats. The variety used for this study had a white seed coat. This could account for the low content of tannin obtained. Moreover, the work of Singh (1988) was mainly on the seeds while the present study focused on the forage.

5.1.5 **Mineral content of diet**

The calcium and phosphors contents of all the treatment diets were within the range of 1:1 to 7:1 that can be tolerated by ruminants (Ogundipe, 2005). The most appropriate ratio of 2:1 Ca: P recommended by ARC (1984) obtained in all the treatments except for pigeon pea forage supplementation at 1.5% of body weight where the ratio was slightly less (2.88 Ca and 1.22 P).

Optimum mineral requirement for sheep at maintenance level is 1.2g/day Ca, 0.9g/day P, Na 250, Mg 600, Fe 500, K 500 and S 1400 mg/Kg DM (Kearl, 1982). Values obtained in this study fell within this requirement and therefore met the ewes maintenance needs.

5.1.6 **Feed intake**

There was an increase in DM intake as the level of pigeon pea increased in the diets. This is similar to work of Moran *et al* (1983), who reported an increase in DM intake when rice straw was supplemented with *Leuceana leueocephala*. Richard *et al* (1994) also reported increase in feed intake when crop residues with poor nitrogen levels were supplemented with legume forages. Brown and Pitman (1991), however stated that in some cases the use of legume supplement at between 10-20% had increased animal performance without significant increase in intake. The decline in DM intake at 1.5 percent of body weight pigeon pea forage supplementation agrees with the work of Muanyuchi *et al* (1997). They found that forage supplementation increased total feed intake up to a point. Beyond 20-40 percent legume supplementation, the intake of the diet fell below the

unsupplemented basal diet. Mosi and Butterworth (1984), also reported a decline in the intake of maize stover when inclusion of *Trifolium tembense* exceeded 34.7 percent.

The differences in the level of response may depend on type and level of supplementation. Sujatha *et al* (1998) fed three forages namely *Leuceana leucocephala*, *Gliricidia sepium* and *Trifolium tembense* hay to a basal diet of rice straw. They obtained variable responses. This also agrees with the work of Dutta *et al* (1999). In this study, pigeon pea supplementation increased DM intake at 0.5 and 1.0 percent body weight supplementation. Increase Singh pigeon pea forage supplementation to 1.5 percent decreased DM intake significantly.

There was a decline in silica intake as the level of pigeon pea consumed increased. This could be because increase in the intake of pigeon pea forage was followed by a corresponding decrease in the basal rice straw, which contained the silica. The opposite was obtained for tannin content. The intake of tannin increased from 31.77mg/kg at 0.5 pigeon pea supplementation to 65.94mg/kg at 1.5 percent. These tannin levels were too low to cause deleterious effect to ewes. Donnelly and Anthony (1969) reported that the tannin level required for rejection by grazing animals is about 20mg/g of DM. Tagari *et al* (1976) stated that the threshold of toxicity of tannic acid added directly to rumen content in fistulated animals was 6.6g tannin/kg. In this study, pigeon pea forage supplementation increased DM intake from 534.89g/day at the unsupplemented diet to 594.56g/day at 1.0% body weight supplementation beyond this level the daily DM intake declined.

There was a linear increase in total DM intake as the level of pigeon pea forage increased from 0.0 percent to 1.5 percent of body weight. This increase was however, not significant. This agrees with the report of Moran *et al* (1983). They found that there was increase in DM intake when rice straw was supplemented with *Leuceana leucocephala*. Hennessey *et al*. (1985) explained that supplementary protein apparently removed the restriction on voluntary intake by providing nitrogenous substrate for rumen fermentation and extra amino acids of microbial and dietary origin for absorption from the small intestine.

5.1.7 **Weight changes and feed efficiency.**

There was a decrease in weight in ewes fed rice straw alone (0.0%) and rice straw supplemented with 0.5 percent pigeon pea forage. Anshua *et al* (1997) reported similar result. The authors attributed this to the low digestibility, low mineral and energy content. Moran *et al* (1993), also reported low digestibility coefficient, metabolizable energy content and negative mineral balances when Ongola cattle were fed on rice straw and alkali treated rice straw. The poor DM digestibility values of 13.05 and 16.09 percent obtained in this study for 0 and 0.5% body weight supplementation was unable to maintain body weight in the ewes. This study confirm the inability of ruminants to maintain live weight on a diet consisting solely of rice straw Sujatha (1998) reported a negative balance of – 74mg/kgW $^{0.75}$/day for sheep fed solely rice straw.

The weight increase recorded when pigeon pea supplementation increased to 1.0 and 1.5 percent of body weight was similar to report of Parez *et al* (1979). They reported growth rate of 0.38g/day in Zebu bulls fed ad *libitum* on 60 percent rice straw and 40 percent *Leuceana* with DM intake of 105g/kgW$^{0.75}$/day. They also found that increase Singh *Leuceana* to 90 percent of the total diet did not increase appetite or growth. This is similar to the result obtained in this study where increase Singh pigeon pea forage to 1.5 percent of body weight did not cause any increase either in feed intake or weight gain. Hannesy *et al* (1985) worked with carpet grass and found that young cattle could not maintain live weight when fed unimproved carpet grass. They found that the addition of protein pellets, however, increased live weight. Thus indicating that this form of

supplementation removed the major nutritional limitation imposed by the basal diet. Working with sheep, Premarantne *et al* (1998) also reported a decrease in weight of 1.7g/$^{kg}W^{0.75}$/day when sheep were fed solely on rice straw; but supplementation with *Leuceana and Gliricidia, spp* and *Trifolium tembense* hay resulted in a daily weight gain of 5.2, 5.4 and 4.7g/kg$W^{0.75}$/ day, respectively.

> Given the low digestibility of treatment diets, it was not surprising that the ewes had to consume large amounts of rice straw and pigeon pea forage in 1.0 and 1.5 percent supplement to maintain body weight. The feed efficiency ratios were therefore, low. Generally, the major limitation to the feeding of fibrous crop residues is whether the animal can voluntarily consume enough feed material required for it maintenance and production. The values obtained in this study (473.25 and 518g/day) are close to 3.0 percent of body weight (450g/day) DM intake recommended by Kearl (1982), for maintenance by sheep feeding on crop residues in developing countries. This study therefore, showed that for ewes to maintain body weight on rice straw based diet, pigeon pea forage should be supplemented at 1.0% of body weight.

5.2 **Nutrient digestibility and nitrogen balance**

The result shows a high percentage of nitrogen retention across all treatments. This could be because many protein nitrogen sources released ammonia at lower rate than urea-nitrogen, more closely coinciding with the release of energy from the cellulose component thereby enhancing microbial production. Roffler *el al* (1976) stated that the synchronization of rate of degradation of nitrogen and carbohydrate components in the rumen was important for the synthesis of microbial protein. Ørskov (1982) further stated that microbial protein in the rumen accounts for 60-85 percent of the total amino acid entering the small intestine. The pattern of degradation of nitrogen is therefore, a major factor influencing its retention for efficient utilization of crop residues.

A significant difference in percentage digestibility of DM, OM NDF and ADF across the treatments was observed in this study. One percent body weight supplementation of pigeon pea forage gave better results in all these parameters even though it was not significantly different from the 1.5 percent body weight supplementation. The values obtained at 1.0 percent body weight supplementation though similar were slightly lower than results obtained by Moran *et al* (1983) who fed alkali treated rice straw to Ongola cattle and buffalo. They reported 37.6 and 46.0 digestion coefficient for DM and OM, respectively. Rahal *et al* (1997) showed that there were varietal differences in voluntary intake and *in vitro* digestibility of different cultivars of rice straw. They also reported a range of 490 to 587g/kg OM digestibility for three varieties of rice.

Generally, the digestibility of rice straw and rice straw based diets especially for 0.0 and 0.5 percent pigeon pea forage supplement was poor. The rice straw used in this study contains both silica (4.27%) and lignin (5.11%); these components tend to limit cell wall digestion. Shimojo and Goto (1989) reported that silica exerts an anti-microbial effect. Yantyati *et al* (1987) also reported the same effect for lignin. They explained that silica and lignin present a formidable physical barrier to rumen microorganisms. Other workers however explained that the presence of silica reduces the amount of digestible components in the straw (Yantyati and Akira, 1989).

The slight decline in digestibility recorded when pigeon pea inclusion exceeded 1.0 percent of body weight agrees with the work of Cann, *et al*., (1993).

They stated that digestibility increased with increase in the level of crude protein in the diet up to a point. Once the level of nitrogen deficiency of crop residues had been overcome, there is little or no advantage in feeding additional forage legume. Since the nitrogen deficiency in the rumen was met at 1.0 percent body weight supplementation with pigeon pea forage, the next factor limiting the amount of protein synthesize by rumen micro organisms and the rate at which they ferment roughages is likely to be the amount of readily available energy in the feed. This study has therefore, shown that pigeon pea forage in addition to correcting the deficiency of rumen degradable nitrogen from 53.49g/day to 65.83g/day also increase the amount of rumen degradable organic matter from 24.21% to 42.62%.

5.3 METABOLITES STUDY

5.3.1 Plasma Urea Nitrogen

The uniformly low plasma urea nitrogen levels obtained in the control diet is indicative of the low dietary protein level as well as the reduced microbial activity in the rumen. However, the higher plasma urea concentration at 0.5 to 1.5 percent of body weight pigeon pea forage supplementation showed the increase in microbial degradation as a result of increased protein supplied to the rumen. Blood urea nitrogen accurately reflects the intake of effective rumen degradable protein and its balance with fermentable metabolisable energy.

Except for the unsupplemented diet, the plasma urea nitrogen levels was similar to what was reported (5.56 and 4.24) by Moloney *et al* (1994) when they fed grass silage supplemented with barley or molasses based supplements. Rumen

ammonia enters the plasma urea pool after it has been absorbed into the blood and is converted to urea by the liver. The increased concentration of plasma urea nitrogen particularly at 6hrs post feeding indicates the rate of microbial digestion of the available protein in pigeon pea forage. Plasma urea nitrogen levels obtained in this study were of low to medium levels (2.0 – 6.37). Woodman and Evans (1974) stated that a high value of plasma urea nitrogen indicates a poor ability of the animal to utilize nitrogen made available by digestion. This agrees with the high nitrogen retention results (86.19% - 90.06%) obtained in this study.

The presence of tannin at high concentration had also been shown to reduce plasma urea nitrogen level. Reed *et al* (1990) showed that plasma urea nitrogen was higher in animals fed diets of *Sesbania sesban* compared to those fed with *Acacia brevispica*. Similar results was reported by Rittner (1987) when he compared diets containing *Sesbania sesban* with diets containing *Acacia seyal* and *Acacia nilotica.* Reed (1995) attributed these differences to their high tannin content which affected protein digestibility. The tannin content of this pigeon pea forage (0.5mg/kg) is too low to have such an effect. Tannin levels that could have negative effect in sheep and goats were reported to be within the range of 8-10% of the diet (Bejovic *et al* 1978). This study has shown that even though pigeon pea forage contained some amount of tannin (0.5mg/kg) it was not enough to cause a deleterious effect on microbial digestion and utilization of nitrogen contained in the forage.

5.3.2 **Rumen ammonia**

Rumen ammonia nitrogen is a measure of the extent of rumen microbial protein degradation. The result of this study showed a generally low level of ammonia – nitrogen in the 0.0 percent pigeon pea diet. The significant low increase in ammonia – nitrogen concentration at 6 and 9 hours in this treatment indicates slow and poor protein degradability in rice straw. Sujatha *et al* (1998) obtained nitrogen balance of -74mg for sheep fed solely on rice straw. A decrease in protein degradability implying reduced rumen ammonia nitrogen has been associated with reduced rumen microbial population and fermentation; thus leading to reduced feed intake. Inclusion of pigeon pea forage to the basal rice straw diet improved the levels of rumen ammonia – nitrogen in the diets. The use of pigeon pea forage at 1.0 and 1.5% of body weight increased uniformly the levels of rumen ammonia nitrogen within the 24 hours studied.

This indicates a more stable rumen environment which is necessary for efficient microbial fermentation. Ørskov (1982) stated that the requirement for rumen degradable protein (RDP) is considerably less with straw than for concentrates because straw is less digestible. If more RDP is given than the microbes can utilize, it will simply be wasted and excreted in the urine. Also Alawa (1999) had also stated that animals may maintain their weights by increasing the intake of crop residues and other low quality by–products if protein with moderate degradation within the rumen is reasonably supplied. The low ammonia – nitrogen levels obtained across the treatments was not uncommon.

Satter and Slyter (1974) and Satter and Roffler (1976) reported 1-5mg/l as the optimum ammonia concentration for microbial growth, while Pawel *et al* (1981) in *in-vivo* experiments reported 3.6 to 17mg/l. The values obtained in this study were in agreement with these reports. The concentration of ammonia which promotes maximum microbial protein production is an important factor determining the utilization of the nitrogen in the rumen. Indeed a feeding scheme for ruminants in which rumen ammonia concentration plays a key role had been proposed by Slater and Roffler (1976).

5.3.3 **Volatile fatty acids.**

The volatile fatty acids results showed increase in the level of volatile fatty acid as the level of pigeon pea forage supplementation increased up to 1.0 percent of body weight. The slight non significant decline at 1.5 percent body weight supplementation agrees with the work of Ørskov (1982) who reported that once the nitrogen limitation in the rumen is corrected, there may be no advantage in increasing nitrogen level. Volatile fatty acids are the main energy sources for ruminants feeding mainly on roughages. Their levels in these treatments gave an indication of the energy value of the feeds. The increase in volatile fatty acids from 19.87 in 0.0 percent treatment to 36.57 mm/l in 1.0 percent pigeon pea forage supplementation could be associated with the increase in digestibility of the feed material (Ørskov and Ryle, 1990).

5.3.4 **Rumen pH**

Though there were significant variations in pH within treatments across sampling hours, these variations were within normal pH range of the rumen environment. It was only at 24 hours post-feeding for 0.5, 1.0 and 1.5 percent of body weight inclusion of pigeon pea forage that rumen pH exceeded the normal range of 6.2 – 6.9. Inclusion of pigeon pea forage to rice straw based diets changed the rumen pH at 24 hours post-feeding to slightly alkaline (7.10-7.31). Grants and Mertens, (1992) reported that higher rumen fluid pH is conducive for cellulose digestion. Nangia and Sharma (1994) further explained that higher rumen pH increases rumen flow rate. This according to them leads to washing out of old bacteria cultures known for higher hemicelluloses activity. This study did not measure cellulose and hemicelluloses digestion in the experimental diets at 24 hours post feeding. Therefore conclusive statement cannot be made regarding the digestibility of cellulose and hemicelluloses at 24hours post-feeding. Though significant differences exist in pH across treatments, (0.5 and 1.5 being similar and significantly different from 0.0 and 1.0%) the pH range obtained was within the range for optimal rumen fermentation. Ørskov (1982) stated that when straw, or poor-to-maximum quality hay are fed, the rumen pH stabilizes at about 6.8 to 7.0.

Within the 24hours studied, the feed materials did not cause any significant change in the pH of the rumen environment. The pH remained conducive for optimum microbial digestion.

5.3.5 **Rumen fluid mineral level**

The mineral levels obtained in this study were within the range required by sheep for maintenance (Kearl, 1982). The agronomic practices (fertilizer applications) for both the rice and pigeon pea ensured good mineral content in the soil and by extension the straw and forage. The fact that rice straw was collected at harvest and stored in an airy room also eliminated possible deterioration of the straw. Leaf shattering which is a common problem with leguminous forages was properly checked by drying the forage in an airy room after 4 days wilting.

The result of the mineral content in rumen fluid showed a high Ca: P. ratio. Ogundipe (2005) stated that ruminants can tolerate Ca: P of up to 7:1. The mineral content presented were however obtained from rumen fluid samples. Blood level of these minerals may give a better indication of their levels in sheep (Ogundipe, 2005).

This study has shown that supplementing rice straw base diet with pigeon forage increased the mean levels of NH_3-N and VFA from 2.93 mg/l to 7.60mg/l and 19.87 mm/l to 36.57mm/l respectively. Mean level of plasma urea nitrogen also increased from 2.52mm/l in the unsupplemented ewes to 4.94 mm/l in 1.0% of body weight pigeon pea forage supplementation. This increase was also obtained during the sampling hours post-feeding. Mean levels of PCV and haemoglobin also improved from 21.00% to 32.00% and 48.00% to 73.00%, respectively. This study therefore, improved the levels of rumen and blood metabolites in yearling Yankasa ewes.

5.3.6 **Mean blood variables**

The positive influence of diets on blood parameters reported in this study is in agreement with the work of Rekwot (1997) who observed that feeding levels affected haemoglobin and packed cell volume. The mean concentrations of blood variables; packed cell volume, haemoglobin and white blood count obtained in this study except for the unsupplemented rice straw are within average values. They were within the range of 39.79 – 41.42% packed cell volume reported by Moloney *et al*., (1994) when they fed grass silage and rolled barley or sugar cane molasses based supplements to steers. There is a relationship between nutrition and blood profile; protein deficiency can lead to clinical anaemia due to decreased erythrocytes and hypo-proteinemia. (Alabi, 2005). Hewet (1974) reported that the plane of nutrition affects haemoglobin level. Haemoglobin is important for oxygen transport. Saror and Coles (1975) had reported lower packed cell volume and haemoglobin values for zebu cattle under native husbandry practices.

5.4 **GAS PRODUCTION**

The pattern of gas production showed fast rate of fermentation leading to high amount of gas produced within the first 3 hours with a subsequent decline in rate of gas production up to 48 hours. This was similar to report of Khazaal *et al* (1995). In their work however, they measured gas production at 12, 24 and 48 hours only. This pattern was however, not observed in the work of Bogoro *et al*. (1999) which showed higher production after the first 12 hours.

The mean values of gas produced from the treatment diets at 24 hours, were lower than values reported by Ramachandra and Krishnamoorthy (2000) who measured gas production from untreated (39.15 ml/24hr) and urea treated (28.43 – 37.22 ml/24hr) ragi straw. The values were also lower than the report of Khazaal *et al* (1995) who incubated Rye grass, Triticale and oats at different stages of growth. The variations observed could be attributed to the nature of the forages involved, treatment given to these forages as well as their stage of maturity. Valentine *et al* (1999) also stated that factors such as methodology used, type of animals, and number of measurements and hence precision of the degradation curve could affect the results obtained.

The pattern and total amount of gas produced from a particular feed material appears to be a function of the chemical nature of the feed. Rice straw contains silica and a waxy cutin layer covering the outer surfaces of the leaf. Studies have shown that the cuticle is not degraded (Yantyati, *et al* 1987). The cutin is removed from plant tissue during digestion only by preferential microbial attack on underlying epidermal cells (Akin, 1989). Furthermore, the digestion of rice straw is essentially limited to damaged regions of the cuticle and to cut ends (Akin, 1989). This implies that if rice straw escaped extensive damage during mastication, the cuticle can be a major barrier to microbial digestion. This would ultimately affect both the rate and extent of the gas produced.

Given all these factors, the role of increased protein supplied to the rumen microbes in the form of pigeon pea forage is apparent by the increase in both

amount and rate of gas produced in the treatment diets which was a consequence of increased microbial production.

The fermentation characteristics obtained by fitting the data of gas production into the exponential equation showed that the potential gas produced increased significantly due to the supplementation effect up to 1.0% of body weight. These results were lower than what was reported by Khazaal *et al* (1993a).

The use of potential gas production (a + b) to predict animal performance showed poor results. This was in agreement with the work of Khazaal *et al* (1995). The failure of the gas test to accurately predict intake, *in vivo* apparent DMD and growth may be due to the differences arising from the fermentation process. In the rumen, proteins are deaminated and the resulting keto acids are decarboxylated. The remaining fatty acids and ammonia are used for microbial growth or absorbed through the rumen wall. However, the fermentation process leads to the formation of ammonium bicarbonate (NH_4HCO_3) from carbon dioxide (CO_2) and ammonia (NH_3) and therefore reduces the contribution of CO_2 to gas production (Menke and Steingass, 1988). Furthermore the production of ammonium bicarbonate would increase the buffering capacity of the medium leading to reduced CO_2 pushed out of the medium due to lower pH. Khazaal *et al* (1993a) stated that to obtain full description, periods of at least 72 or 120h is required. The amount of gas production obtained from this study was low. This could be due to the nature of

rice straw. The (a + b) potential gas produced was poor in predicting performance parameters.

5.5 RUMEN KINETICS

The poor digestibility of rice straw as observed in this study has been reported by many workers (Akin, 1989, Yantyati *et al* 1987 and Shimojo and Goto, 1989). Increasing the level of pigeon pea forage resulted in an increase in the level of water soluble component (a) of the diet. This indicates that pigeon pea forage contains reasonable quantity of readily degradable nutrients. Khazaal *et al* (1995) also stated that an average leguminous hay has fast degradation rates.

The a values ranged from 10.79 in the unsupplemented diet to 72.17g/kg DM in 1.5% of body weight supplementation. This agrees with the results of rumen metabolites such as volatile fatty acids, rumen ammonia as well as the blood metabolite plasma urea nitrogen. These metabolites showed high production levels in the first 6 hours post-feeding.

The potential degradability (a + b) of the diet also improved up to 1.0% supplementation level. These values were however lower than the results obtained by Khazaal (1995) who studied the degradation characteristics of 10 hays and obtained a range of 60.50 to 86.00% degradability and by Shem *et al* (1995) who worked on unsupplemented and urea supplement crop residues. Bogoro *et al* (1999) also reported higher degradation percentages for sorghum stover. Khazaal *et al* (1993a) suggested that the presence of antinutritive factors such as tannins,

coupled with a high water soluble fraction (a) could lead to higher passage rate and binding of substrate to tannins thus reducing digestion. This may explain the lower values obtained in this study, given that the pigeon pea forage used contained (0.5mg/kg) tannin and a high water soluble fraction. This also agreed with the low digestibility values obtained in the digestibility study and the significant decline in potential degradability of the diet at 1.5% of body weight pigeon pea supplementation.

The potential DM degradation (a + b) gave good predictions of intake, apparent digestibility and growth. This agreed with the report of Blummel and Ørskov (1993) and Ørskov (1982). According to Khazaal *et al* (1993a) it is because the nylon bag production identifies real entities namely water soluble fraction (a) and the insoluble but degradable fraction (b); whereas the constants a and b in the gas production method are derivatives which may be less connected with reality.

5.5.1 **Correlation of gas production and DM degradation**

The positive correlation indicates that the level of gas production increases with *in sacco* dry matter degradation up to 24h (r = 0.62 to 0.88) for all the treatments. Similar positive correlation was reported by Blummel and Ørskov (1993), Shem *et al*, (1995). Khazaal *et al*, (1995) also obtained positive correlation between dry mater intake, dry matter digestibility and gas production for 10 graminaceous hay individually offered. They reported r = 0.66 between gas production and DM digestibility. The practical implication of this result is that it is

possible to advice farmers on the potential use and nutritional limitations of the use of some fibrous crop residues. This study showed that the amount of gas produced is positively correlated to DM degradation *in sacco*. It can therefore be used to estimate degradation characteristics *in vivo*.

5.5.2 **Predictive equations of gas production against volatile fatty acids and DM degradation.**

Valentine *et al* (1999) stated that the ability to ration cattle and sheep according to requirement depends to a large extent on the accuracy with which the quantity and quality of forages offered and consumed can be estimated. The results shown by the quadratic regression equation $Y= a + bx – cx^2$ indicated significant R^2 values. This implies that for all the treatments, gas production *in vitro* can be used to accurately predict DM degradation in the rumen as well as volalile fatty acid production in the rumen. Similar results had been reported by Khazaal *et al* (1993a); (1995). They concluded that gas test had good potential for predicting not only apparent digestibility but also intake to a level close to that of nylon bag technique. Bogoro *et al*, (1999) stated that the gas production method of feed assessment is reported to be better than *in vivo* rumen degradation kinetics especially for feeds known to contain some antinutritive factors. These workers suggested the use of both *in sacco* rumen degradability technique and *in-vitro* rumen gas technique as predictors of chemical and nutritive value of feeds.

The prediction of both daily intake and digestibility of roughages by ruminants using simple, reliable and cheap techniques is very important in animal

nutrition. In this study, such precision in the prediction of DMI, DMD and growth using the gas production technique was poor. Gas production should therefore, not be used to estimate production parameters.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Supplementing yearling ewes on a basal rice straw diet had a positive effect on body weight gain. Supplementation at 0.5% of body weight reduced the amount of weight lost by 0.40kg. For the ewes to maintain their live weight, pigeon pea forage should be given at the rate of 1.0% of body weight. Increasing pigeon pea forage to 1.5% of body weight did not result in additional weight gain.

Supplementation of rice straw with pigeon pea forage to sheep also increased DM digestibility from 13.05 in the unsupplemented diet to 33.47 on the 1.0% supplementation. Supplementation resulted in increase in total voluntary DM intake but voluntary intake of the basal rice straw decreased as the level of supplementation increased. Supplementation of rice straw improved the levels of plasma urea nitrogen, rumen ammonia nitrogen and volatile fatty acid with high levels occurring between 6 – 12h post feeding.

pH levels remained within acceptable range for optimum rumen fermentation (6.36 – 7.31). Rumen levels of calcium, phosphorus magnesium, potassium, sodium and iron were within the lower level recommended for sheep on a maintenance ration. Their levels within the 24h profile was stable, same applies to the levels of packed cell volume and haemoglobin.

The gas production technique provided an accurate measure of predicting the amount of volatile fatty acids produced *in vitro* and DM degradation *in vivo* for all the treatments. But the potential gas production (a + b) was poor in predicting performance characteristics such as DM intake, weight gain and DM digestibility.

In sacco nylon-bag degradation was strongly related to amount of gas produced for all treatments (r= 0.62 – 0.88) Therefore, it can be used to estimate gas production. The potential degradation (A + B) *in vitro* was better in predicting voluntary DM intake, weight gain and DM digestibility than gas production *in vitro*.

6.2 Recommendation

Since rice straw alone was unable to maintain body weight of sheep, its supplementation with pigeon pea forage at 1.0% of body weight would enable yearling ewes to maintain body weight. Supplementation with pigeon pea forage at 1.0% of body weight improved total DM intake, nutrient digestibility, levels of rumen and blood metabolites and minerals to the minimum levels acceptable for non-producing animals on a maintenance ration. Thus, poor farmers in the northern part of the country who are unable to use concentrate supplement and experience extreme feed scarcity during the peak of the dry season can therefore use this ration to maintain the body weight of non producing animals. This will help in reducing the weight fluctuations these animals experience between the rainy and dry seasons and the subsequent waste of time and resources that occur

during compensatory growth. Animals will therefore be ready to start production at the onset of the rainy season, when feed materials are in abundance.

Gas production can be used to determine volatile fatty acid produced *in vivo* and DM degradation *in sacco* which are measures of nutrient availability but its production characteristic could not be used to predict performance. Instead the nylon-bag degradation characteristics should be used to predict the performance of sheep on rice straw based diets. It also enables the estimation of rice straw and pigeon pea forage that should be acquired given a certain number of animals.

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Appendix 1: Procedure for the determination of total phenols (Price and Butler 1977)

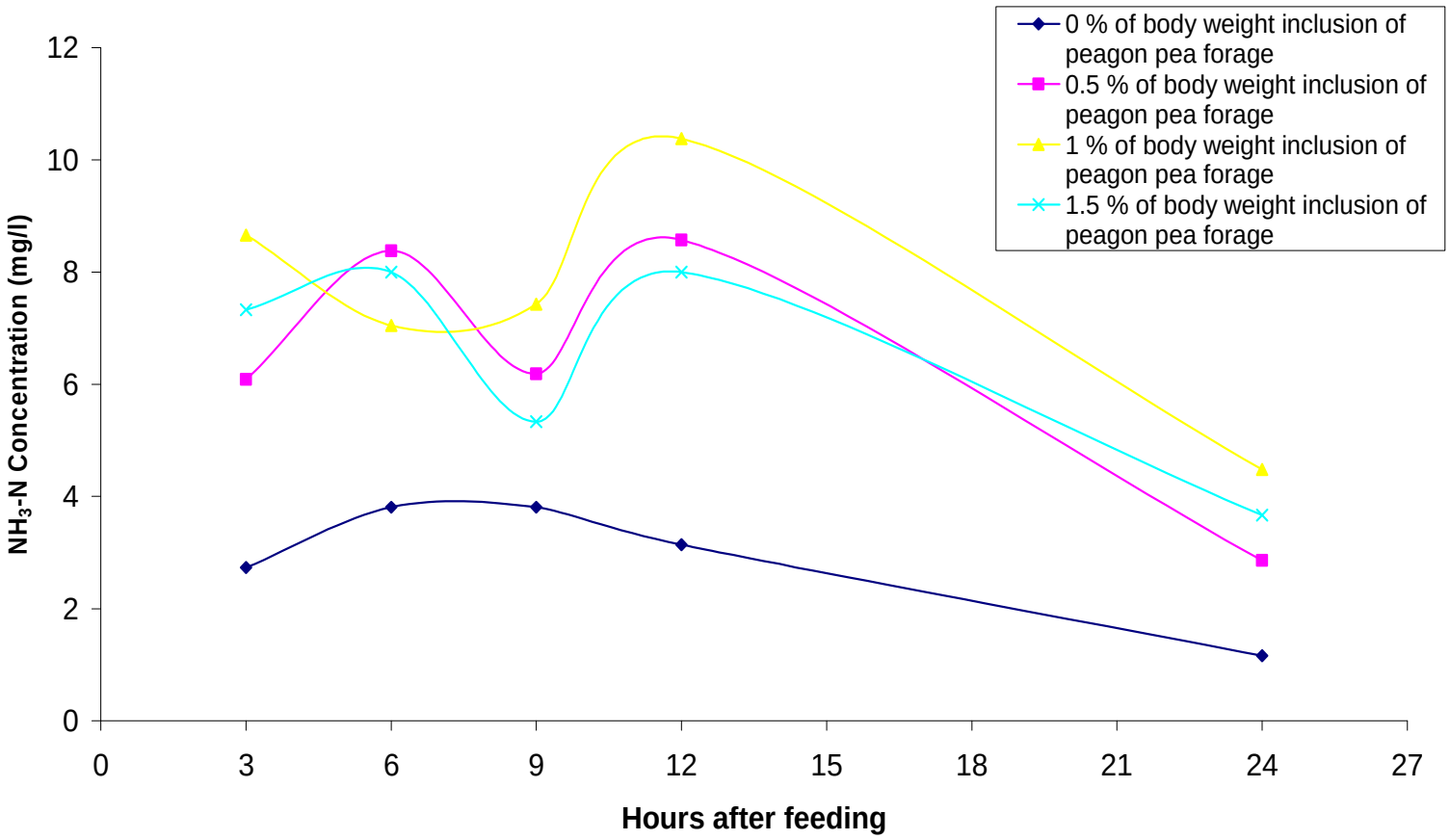
The Prussian blue assay for the determination of total polyphenolics (Price and Butler, 1977) was used. Extraction of 0.035g ground sample (to pass through 1mm screen) was done with 5ml absolute methanol in 30 minutes. This was centrifuged at 6000 rpm for 15 minutes. The supernatant (1ml) was diluted 100 times with distilled water mixed with 0.5ml 0.1M F_eCl_3 in 3ml of 0.1 N HCl for 3 minutes followed by the timed addition of 3ml 0.008 M potassium ferricyanide. The absorption was read after 10 minutes at 720 mm on a spectrophotometer (SP6-400 UV spectrophotometer, PYE UNICAM).

A standard solution according to Gomez *et al*. (1977) was used to draw a standard curve which was used to determine the content of total phenols.

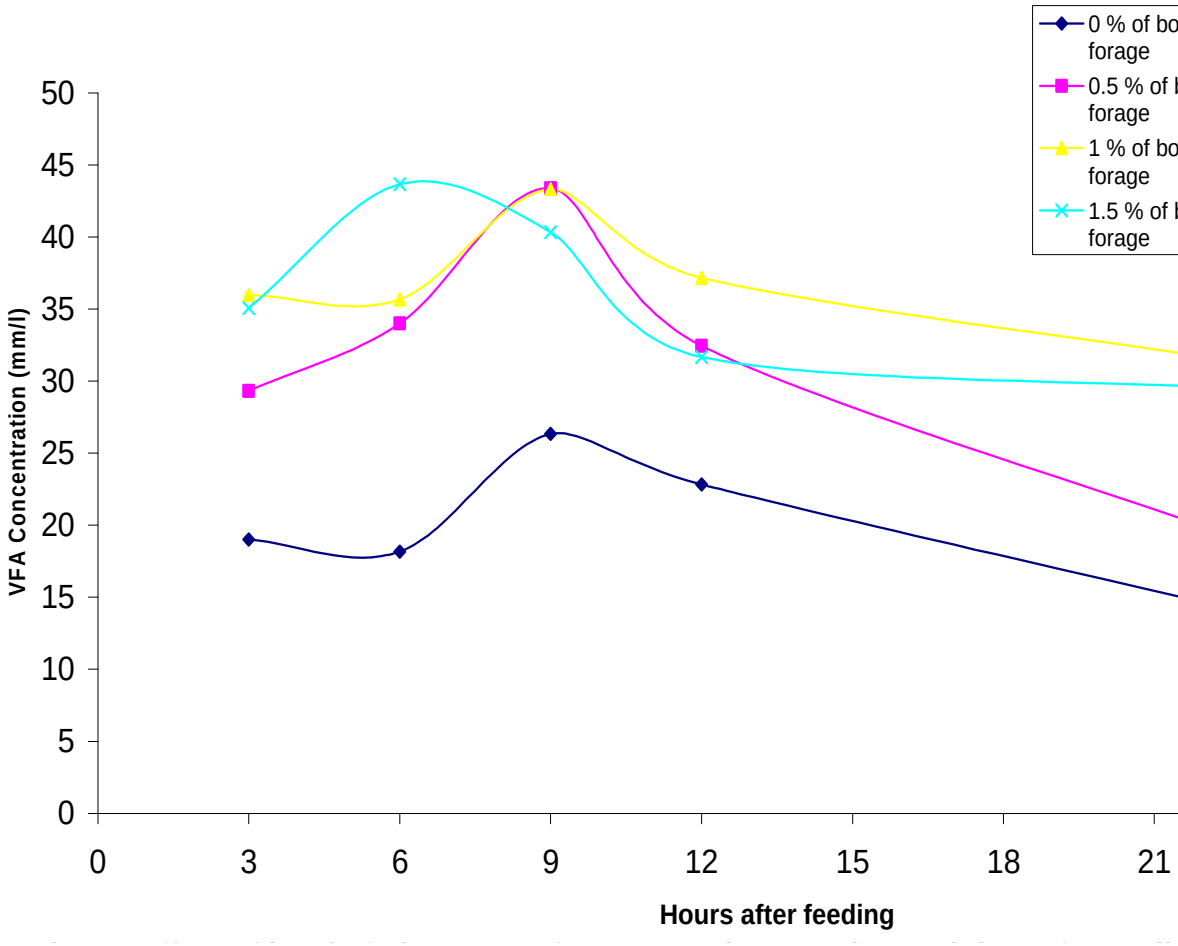
Appendix 2: Procedure for the preparation of rumen liquor medium

One part of liquor was mixed with two parts of a medium consisting of (added in order) 400 ml H_2O, 0.1 ml solution a (13.2g C_aCl_2. $2H_20$, 10.0g $MnCl_2.4H_20$, 1.0g $CoCl_2.6H_20$, 8.0g $FeCl_3.6H_20$ and made up to 100ml with H_20), 200ml solution B (39g $NaHC0_3$/1 H_20), 200ml solution C (5.7g Na_2HPO_4, 6.2g KH_2P0_4, 0.6g $MgSO_4.7H_20$ and made up to 1000ml with H_20), 1ml resazurine (0.1% W/V) and

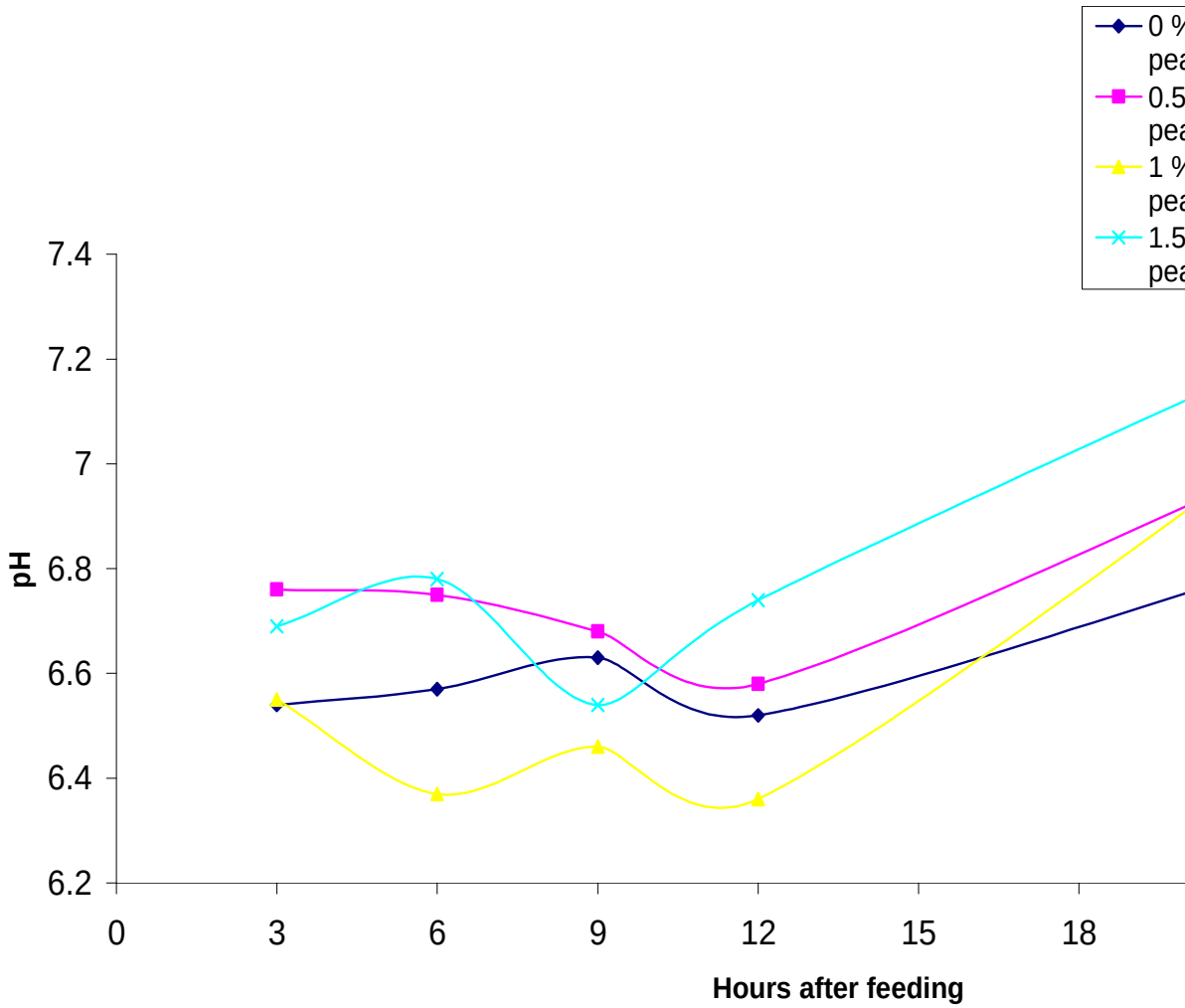
40ml reduction solution (95ml H_20, 4ml 1 N-Na0H and 625mg $Na_2S.9H_20$). The mixture was kept under CO_2 in a water bath at 39^oC and stirred.



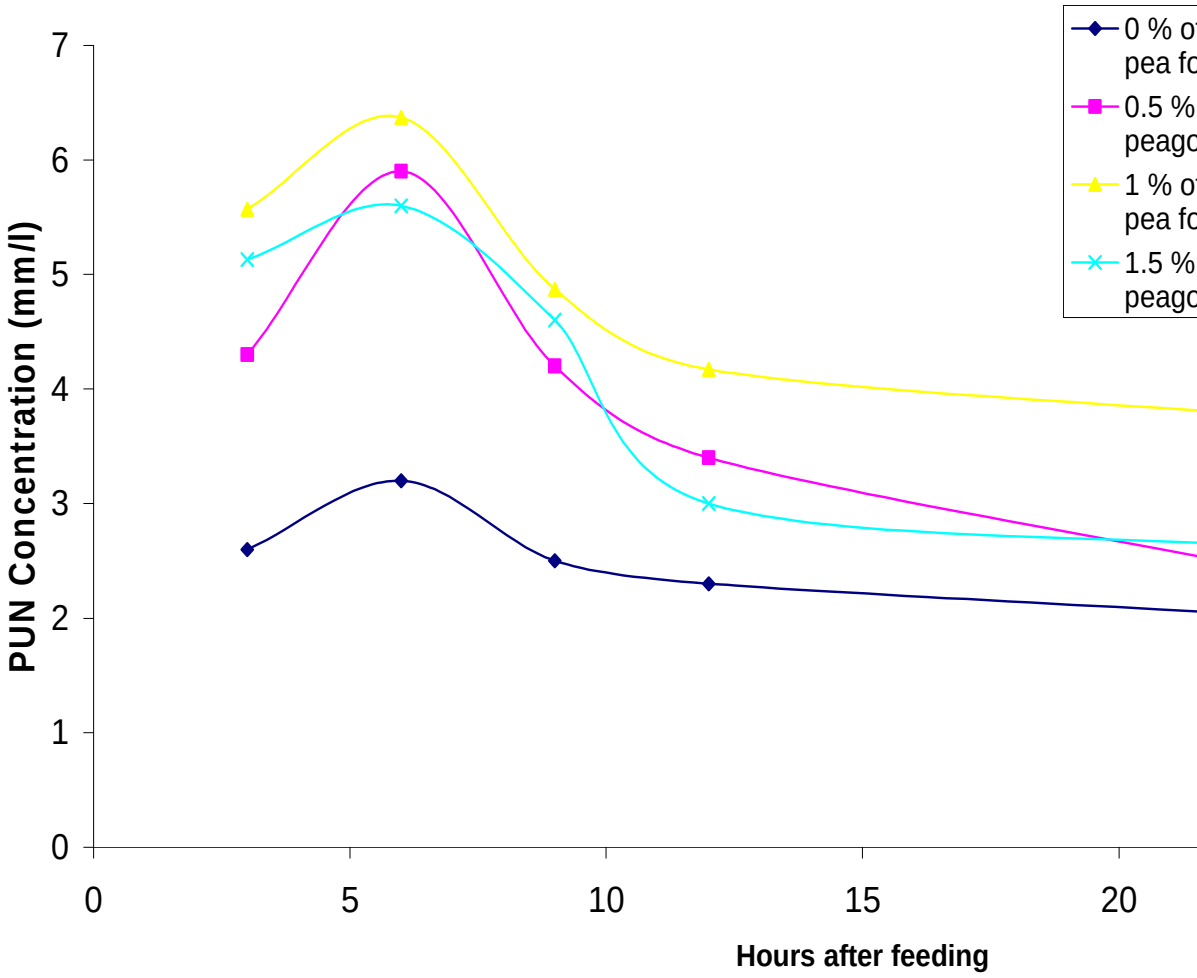
Appendix 3: Trend of NH_3-N concentration (mg/l) of ewes fed rice straw supplemented w



Appendix 4: Trend of VFA concentration (mm/100ml) of ewes fed rice straw supplemented



Appendix 5: Trend of pH in the rumen fluid of ewes fed rice straw supplemented with pige



Appendix 6: Trend of plasma urea nitrogen concentration (mm/1) of ewes fed r
with pigeon pea forage