PERFORMANCE OF GROWING AND FATTENING YANKASA RAMS FED DIFFERENT PROPORTIONS OF UREA TREATED RICE STRAW AND GAMBA HAY

BY

Abdullahi Abdu NAYAWO

B. Agric. (Animal Production, University of Agriculture, Makurdi) 1993

M Sc. Animal Science (Bayero University, Kano) 2010

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DECLARATION

I declare that this Thesis entitled "**Performance of Growing and Fattening Yankasa Rams Fed Different Proportions of Urea Treated Rice Straw and Gamba Hay**" has been carried out by me in the Department of Animal Science, Ahmadu Bello University, Zaria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this Thesis was previously presented for another Degree or Diploma Certificate at this or any other institution

Abdullahi Abdu NAYAWO …… ----------
Signature Date

CERTIFICATION

This Thesis entitled "**PERFORMANCE OF GROWING AND FATTENING YANKASA RAMS FED DIFFERENT PROPORTIONS OF UREA TREATED RICE STRAW AND GAMBA HAY**" by Abdullahi Abdu NAYAWO meets the regulations governing the award of the Degree of Doctor of Philosophy in Animal Science of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation

---------- ----------

Prof. O.W. Ehoche, Date
Chairman Supervisory Committee,
National Animal Production Research Institute,
Ahmadu Bello University,
Zaria.

---------- ----------

Dr. S.B. Abdu, Date
Member Supervisory committee,
Department of Animal Science,
Ahmadu Bello University,
Zaria.

---------- ----------

Dr. S.M. Otaru, Date
Member Supervisory Committee,
National Animal Production Research Institute,
Ahmadu Bello University,
Zaria.

---------- ----------

Prof. S. Duru, Date
Head, Department of Animal Science,
Ahmadu Bello University,
Zaria.

---------- ----------

Prof. K. Bala, Date
Dean, School of Post Graduate Studies,
Ahmadu Bello University,
Zaria.

DEDICATION

This Thesis is dedicated to my beloved parents, late Malama Binta Garba and Alhaji Shu'aibu (Nayawo) Abdu who always prayed for my success.

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First and foremost, I acknowledge the blessings of ALLAH Almighty in my life. I hope He accepts every humble deed I have done and forgives all my sins, faults and shortcomings. Glory is due to All-Knower, Most Gracious and Most Merciful for making it possible for me to actualize this study thus partially immortalizing my efforts towards contributing to the body of knowledge in animal science.

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ABSTRACT

Two trials were conducted for a period of 90 days each to evaluate the feeding value of different proportions of urea treated rice straw and gamba hay in the performance of growing and fattening Yankasa rams. In the first trial, twenty four (24) growing Yankasa rams of mean initial body weight of 15.77±2.5 kg and aged 6 – 8 months were allotted to four dietary treatments with six (6) animals per treatment in a Completely Randomized Design. Urea treated rice straw and gamba hay proportions of 0:60, 20:40, 40:20 and 60:0 were used as roughage diets. A concentrate diet consisting of maize grain, cotton seed cake, rice milling waste, wheat bran, bone meal and salt was formulated to contain 15 % crude protein. The animals were fed roughage diets *ad libitum* while concentrate was fed at 1.5% of individual body weight. Data were collected on growth performance and blood profile. Data generated were subjected to analysis of variance and differences in means were compared using Duncan's Multiple Range Test. The result of chemical analysis showed that treatment of rice straw with urea increased its crude protein content from 3.64 to 8.89 % and decreased the neutral detergent fibre content from 72.16 to 67.98 %. Total dry matter intake varied from 263.11 to 325.01 g/day with the highest value recorded in animals fed 60:0 UTRS:gamba hay diet. Results of crude protein and neutral detergent fibre intake followed similar pattern. The highest ($P<0.05$) average daily gain (79.81 g/day) was obtained in growing rams fed 60:0 UTRS:gamba hay diet while the lowest ($P<0.05$) value (44.44 g/day) was obtained in animals fed 0:60 UTRS:gamba hay diet. Growing rams placed on 60:0 UTRS:gamba hay diet had the lowest ($P<0.05$) feed conversion ratio value (7.77). Dry matter digestibility was significantly ($P<0.05$) affected by UTRS:gamba hay proportions. Animals fed 60:0 UTRS:gamba hay diet had a high dry

matter digestibility (67.62%). The digestibility of other nutrients followed the same pattern. Animals fed 60:0 UTRS:gamba hay diet had significantly (P<0.05) higher nitrogen intake (16.12 g/day) and the lowest (P<0.05) in the diet containing 0:60 UTRS:gamba hay (12.06 g/day). Nitrogen balance significantly (P<0.05) differed across the dietary treatments. Animals fed diet containing 60:0 UTRS:gamba hay had high nitrogen retention (13.30 g/day) while those fed 0:60 UTRS:gamba hay diet had low nitrogen retention (7.78 g/day). With exception of serum creatinine, all the serum parameters measured were significantly (P<0.05) different. Animals on 60:0 UTRS:gamba hay diet had higher (P<0.05) value of serum glucose (61.02 mg/dl) while animals fed 0:60 UTRS:gamba hay diet had the lowest (P<0.05) value (49.55 mg/dl). Serum urea nitrogen and total protein followed similar pattern. In the second trial, twenty (20) intact Yankasa rams with mean initial body weight of 21.87±2 kg and aged 12 – 18 months were allotted to four dietary treatments with five (5) animals per treatment in a Completely Randomized Design. Urea treated rice straw and gamba hay proportions of 0:60, 20:40, 40:20 and 60:0 were used as roughage diets. A concentrate diet consisting of ingredients similar to those of the first trial was formulated to contain 13 % crude protein. The animals were fed roughage diet *ad libitum* while concentrate was fed at 2.0 % of their individual body weight. Data were collected on growth parameters, serum blood profile and rumen liquor metabolites. Data generated were subjected to analysis of variance and differences in means were compared using Duncan's Multiple Range Test. The result of chemical analysis of the experimental diets was similar to that obtained in the growth trial. The result revealed that, there were significant (P<0.05) differences on all the growth parameters measured. Total dry matter intake was significantly (P<0.05)

higher (1035.98 g/day) in animals fed diet containing 60:0 UTRS:gamba hay compared to those fed the rest of the diets. Similarly, animals fed 60:0 UTRS:gamba hay diet had high average daily gain (72.89 g/day) compared to animals on other diets. Lowest ($P<0.05$) value (38.00 g/day) was recorded in animals fed 0:60 UTRS:gamba hay diet. Rams fed 60:0 UTRS:gamba hay diet had the least ($P<0.05$) feed conversion ratio (14.21) indicating that animals on diet containing 60:0 UTRS:gamba hay were more efficient in converting feed to live weight gain than animals fed other diets. Digestibility of nutrients was significantly ($P<0.05$) different across the treatment groups. Total nitrogen intake and nitrogen retention were significantly higher ($P<0.05$) in animals fed diets containing 60:0 and 40:20 UTRS:gamba hay. No significant ($P>0.05$) difference was observed on rumen fluid pH while significant ($P<0.05$) differences were obtained on rumen ammonia nitrogen and Total volatile fatty acids (TVFA). Animals fed 60:0 UTRS:gamba hay diet had higher ($P<0.05$) rumen ammonia nitrogen and TVFA (27.80 mg/dl and 16.13 Mmol/l, respectively). Lowest ($P<0.05$) values (21.79 mg/dl and 12.98 Mmol/l, respectively) were obtained in rams fed 0:60 UTRS:gamba hay diet. Significant ($P<0.05$) differences were observed on all blood profile parameters measured except the serum creatinine. The serum glucose, urea nitrogen and total protein values ranged from 50.29 to 61.32 mg/dl, 5.73 to 8.64 mg/dl and 58.77 to 67.03 g/l, respectively. Values obtained for serum glucose, urea nitrogen, serum creatinine and total protein fell within the normal ranges of 50-100 mg/dl, 15-30 mg/dl, 1-2.7 mg/dl and 60-79 g/l, respectively for sheep. In terms of economic benefit, the results revealed that cost of feed consumed per kg body weight gain (497.76 ₦/kg) was lower and better in fattening rams fed diet containing 60:0 urea treated rice straw:gamba hay proportions. The study recommends that urea treated

rice straw and gamba hay proportions of 60:0 UTRS:gamba hay could be used to replace gamba hay as sole roughage diet for sheep feeding as sheep had higher weight gain in the treated straw based diets compared to gamba hay based diet. The study further recommends that small-holder farmers may adopt the treatment of rice straw with urea to improve its nutritive value and reduce the cost of feed per kg body weight gain.

CHAPTER ONE

1.0 INTRODUCTION

Sheep are important part of the global agricultural economy and they play a major role in many local economies (Weaver, 2005). Njidda and Kibon (2004) stated that sheep are multipurpose animals, but they are primarily kept for the production of meat (mutton), and they account for about 11% of the total meat supply in Nigeria. The authors further stated that the inclusion of animals slaughtered in the rural areas outside the slaughter houses would have made this figure higher. Afolayan (1996) reported that Yankasa sheep is very popular among sheep farmers, most especially in northern Nigeria. Their high productivity in terms of growth performance and prolificacy are paramount to the farmer (Akpa *et al.*, 2006). Inadequate and poor quality of feed, especially during the long dry season is one of the major factors militating against livestock production in Nigeria. The seasonality of feed supply in northern Nigeria has affected animal production adversely (FDLPCS, 1992).

According to Rumirez-Orduna *et al*. (2005), due to high cost, most smallholder livestock farmers cannot afford to supplement the diet of their animals with expensive feed ingredients. Production of livestock and their productivity are far below the population's requirement for animal protein. This under-production and low productivity are attributed mainly to inadequate year-round availability of feed and water, coupled with poor management (Abbey *et al*., 2001). In the Savannah zone of Nigeria the basal diets of most ruminants in the dry season is based on crop residues and dry standing grasses, and most of these feed resources are imbalanced in nutritional value and vary from year to year (Zemmelink, 1999).

The natural rangeland serves as the major sources of forages for ruminants in Nigeria. Rangeland forages, however, decline in both quality and quantity during the dry season, resulting in low productivity of animals. Gamba (*Andropogon gayanus*) is a tropical grass which is widely distributed throughout the savanna ecology of Nigeria and forms the bulk of feed available to ruminants grazing on rangelands (Fitzhugh, 1978). Gamba grass is usually established as permanent pasture in most commercial ranches or smallholder farms. It can be cut as fresh feed or conserved as hay. The crude protein content of gamba grass is moderate in young growth (7 - 10%) but declines rapidly with maturity (2 - 5%) (Leeuw, 1979; Agishi, 1985). Alli-Balogun (2010) reported CP, NDF and ADF contents of gamba hay as 3.76, 76.4 and 56.2%, respectively.

Rice straw, like other cereal crop residues is a potential source of energy for ruminants. However, its potential as an energy source is limited because it is high in dietary fibre (>50%) and low in crude protein (2 - 7%) and mineral contents (0.02 - 0.16%) (Sundstol and Owen, 1984; Jung *et al*., 1993). One way in which, the low nutritive value of rice straws could be improved, is through treatment with urea. In feeding trial strategies for improving milk production by Ehoche (2002), urea treatment of crop residues is acknowledged to improve nutritional value of crop residues and other fibrous by-products and reduce feed cost and wastages with practical application at the smallholder level in developing countries. The author further stated that in the tropics, cereal crop residues such as maize, sorghum, millet stover and rice straw were produced in large quantities and could be used as ruminant livestock feeds. Akande (2001) reported that in Nigeria, rice is cultivated in virtually all agro-ecological zones and the residue (straw) can be

obtained or purchased at relatively cheap or free of charge from all rice farms. According to FAO (2012), Nigeria is the second largest producer of rice in Africa after Egypt and the largest in West Africa. FAO (2013) reported that Nigeria production of paddy rice was estimated at 4,700,000 tonnes. This gives rise to increase in rice straw output in the country which could be harnessed for ruminant livestock feeding. It was also reported by Parnich (1983) that, information on the utilization of rice straw in the diets of sheep is scanty. The use of rice straws could help improve ruminant livestock production, if its nutritive value is enhanced.

1.1 Justification

Utilization of crop residues as feed has been the subject of intense research and development worldwide since the mid1970s but there appears little effort has resulted in greater utilization of crop residues in developing countries (Owen and Jayasuriya, 1989. Kalio *et al*. (2013) reported that in Nigeria, millions of tons of crop by-products are generated every year in our rural communities as unavoidable crop by products or residues. Akande (2001) reported that in Nigeria, rice is cultivated in virtually all agro-ecological zones. There is a tendency that paddy rice will be more available in future through the recent Presidential initiative on rice production in Nigeria which is aimed at encouraging local rice production in order to reduce over-dependence of the country on imported rice (James, 2011) which means increase in rice straw output in the country. Due to lack of adequate disposal facilities, most of the rice straw generated from rice farming in Nigeria are left in the fields to be partially grazed by large ruminants only without small ruminants benefitting as rice straw is inefficiently utilized by them because

of its high fibre content. Jung *et al*. (1993) reported that the potential of rice straw as energy source is limited because of the complex lignified cell wall structure, which shields the energy yielding nutrients from microbial degradation in the rumen. Most small ruminant farmers therefore, do not utilize the straw in feeding their animals but left it in the fields to rot or burned in situ, resulting in pollution of environment as well as causing soil erosion.

In recent time, there is concern on global warming due to burning of wastes. Akinfemi and Ogunwole (2012) reported that burning of rice straw increases particle matter into the atmosphere as well as increases atmospheric temperature by carbon dioxide emission, thus increasing global warming Such global concern necessitated alternative option of recycling of waste into beneficial products. Therefore, Feeding rice straw to livestock will not only serve as potential energy source for ruminants but will reduce its environmental impact.

Treatment of rice straw with urea for feeding of ruminants has been given more attention and has proved to be effective (Doyle *et al.*, 1986; Schiere and Ibrahim, 1989; Chenost and Kayouli 1997). However, the technology has not been widely practiced by farmers in Nigeria probably due to inadequate awareness. The study will therefore determine the responses of growing and fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay.

1.2 Aim and objectives of the study

The aim of the study was to improve the nutritive value of rice straw through treatment with urea for feeding small ruminants.

Specific objectives were:

1. To determine the effect of feeding different proportions of urea treated rice straw and (*Andropogon gayanus*) gamba hay on feed intake and nutrient utilization by growing and fattening Yankasa rams.
2. To determine the effect of feeding different proportions of urea treated rice straw and gamba hay on blood serum metabolites of growing and fattening Yankasa rams.
3. To determine the effect of feeding different proportions of urea treated rice straw and gamba hay on rumen fluid metabolites of fattening Yankasa rams.
4. To determine the economic benefit of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay.

1.3 Hypotheses

H_O =Diets containing different proportions of urea treated rice straw and gamba hay have no significant effect on feed intake and nutrient utilization by growing and fattening Yankasa rams.

H_A= Diet containing different proportions of urea treated rice straw and gamba hay have significant effect on feed intake and nutrient utilization by growing and fattening Yankasa rams.

H_O =Diets containing different proportions of urea treated rice straw and gamba hay have no significant effect on blood serum metabolites of growing and fattening Yankasa rams.

H_A= Diet containing different proportions of urea treated rice straw and gamba hay have significant effect on blood serum metabolites of growing and fattening Yankasa rams.

H_O =Diets containing different proportions of urea treated rice straw and gamba hay have no significant effect on rumen fluid metabolites of fattening Yankasa rams.

H_A= Diet containing different proportions of urea treated rice straw and gamba hay have significant effect on rumen fluid metabolites of fattening Yankasa rams.

Ho=Diets containing different proportions of urea treated rice straw and gamba hay have no economic benefit on the fattening of Yankasa rams.

H_A=Diets containing different proportions of urea treated rice straw and gamba hay have economic benefit on the fattening of Yankasa rams.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Small ruminant production in the tropics

Ruminants are kept worldwide for their numerous economic and social contributions to humanity. Recently, more attention has been paid to small ruminants in developing countries as their advantages are becoming more understood than ever before, particularly for their ability to produce meat and milk, even in hostile environments (Aganga and Fabi, 2007). Furthermore, the resistance of small ruminants to the many diseases of cattle and the ease of marketing their products make them the animal of choice for many resource-poor farmers and peri urban livestock farmers (Gatenby, 2002). In a report by FAO (1991), Tropical Africa has about one sixth and about a third of the total world flock of sheep and goats, respectively with an average of an animal per 10 ha of land. Most families in the humid zone of West Africa keep small ruminants (ILCA, 1979).

Small ruminant flock holding sizes are larger in the drier north than in the humid south (Francis, 1988). In South Eastern Nigeria, Francis (1988) reported that goats were more widely owned than sheep. Sheep were owned by 28% of the household contrary to 92% goats' ownership. In South Western Nigeria, average flock size is in the range of 2-5 animals per owner with goats being also more common than sheep.

2.2 Small ruminant population and distribution in Nigeria

Nigeria is endowed with estimated 19.5 million cattle, 72.5 million goats, 41.3 million sheep, 7.1 million pigs, 278,840 camels, 145 million chickens, 11.6 million ducks, 2.1 million turkeys and 974,499 donkeys making the nation the topmost Livestock producer in West Africa (FMARD, 2016). According to Lombin (2007) the population of goats, sheep and cattle in Nigeria were estimated to be 40.8 million, 27 million and 16.3 million respectively. In terms of number, these population figures put Nigeria as the largest producer of livestock in the ECOWAS sub-region. FAO (2008) reported that Nigeria has large population of domestic ruminants in Africa consisting of 52,488,000 goats, 33,080,400 sheep and 16,152,700 cattle. The population of the major domestic animal species found in the semi-arid zone of west African region is said to have increased in the last 30 years (Ben, 2002).

According to Williams *et al*. (2001), the population of cattle, sheep and goats increased by 0.5, 2.2 and 1.7% per year respectively between 1961-63 and 1991- 93. Sheep and goats dominate the livestock population and are said to have higher population compared to any other ruminant species (Garba and Muhammad, 2008) and well adapted to the various ecological zones of Nigeria. About ¾ of the small ruminant population are concentrated in the northern states of Nigeria (Lamorde, 1993). Cattle, sheep and goat distribution in Nigeria is limited by tse-tse fly incidence and by the availability of forage. The semi-arid ecological zone is virtually tse-tse fly free, but has the lowest forage resources, carry over 70% of the total population of livestock in Nigeria are concentrated in the Guinea and Sudan zones (Gefu and Adu, 1982). The trend in ruminant livestock

population in Nigeria is gradually favouring the production of small ruminants compared to cattle. This situation has been attributed to dramatic increase in human population, decreasing land holdings and increase in demands of livestock products (Hoffmann, 2002).

2.3 The place of small ruminants in the Nigerian economy

Livestock sector contributes 5-6% of the gross domestic products (GDP) and 20% of the agricultural component of the gross domestic product of Nigeria (Ikhatua, 2000). Oni (2000) reported that sheep and goats account for about 36% of the total national meat supply and they have tremendous potential for growth. In Nigeria, sheep and goats have always formed an integral part of the domestic economy and source of wealth for Nigerians. It is generally recognized that sheep have a potential to make a significant contribution to food security, poverty reduction and improved livelihoods of smallholder producers in Africa and globally (Perry *et al*., 2003). Small ruminants continue to make substantial contribution to the economy of Nigeria as suppliers of food, raw materials and foreign exchange. Sheep and goats play very important roles in the economy of the small holder farmers as they provide vast range of services apart from meat and milk such as skins and pelts for leather and rugs, risks spreading or for social functions and foreign currency (Adane and Girma, 2008).

In smallholder production systems, goats and sheep are important because they require low initial capital and maintenance costs, are able to use marginal land and crop residues, produce milk and meat in readily usable quantities, and are easily cared for by most

family members. Tibbo (2006) reported that majority of households keep small ruminants; sheep and goats alongside their crops in a mixed farming system due to the fact they have higher reproductive capacity and growth rate. More than 80% of sheep and goats in Nigeria are generally raised by poor farmers and distressed women with little capital inputs (Ranhotra and Jordan, 1996). According to Sarwa *et al*. (2004), sheep and goats have a greater proportion of the total wealth of the poor families than of the rich. The keeping of sheep and goats in any community is related to the value attached to their production. Small ruminants are raised for meat, milk, fiber pelts and skin (Williamson and Payne, 1978). Total meat production from African goats and sheep combined is estimated at 1.15 million tonnes, equivalent to about 16 % of total world output from these species (FAO, 1985).

Sheep and goats do not compete with humans or poultry for food because they can be produced on forage alone and require small quantity of grain or concentrate for good production. Small ruminants form an integral part in the livestock economy production system in Nigeria (Hossain *et al.,* 2002). They continue to make substantial contribution to the economy of Nigeria as supplier of food, raw materials and foreign exchange. Ruminants have major role in balanced agricultural system as converters of low quality feeds to highly desired protein food of high biological value for the benefit of man (Osineye, 2015). Sheep and goats with their small body, high reproductive capacity and rapid growth rates in some instances, are ideally suited to production by resource- poor small holders. They can be integrated into the overall production system, absorbing surplus labour and consuming small amounts of otherwise unused feed. The low capital

requirement for starting or expanding small ruminant production means that risks are low and that the enterprise is well suited to low input systems. In Nigeria, small ruminants represent about 63.70% of the total growing domestic animals (Yakubu *et al.,* 2010). Small ruminant livestock under small holder systems were condemned as scavengers, surviving on crop residues, household wastes and natural vegetation regardless of their quality. However, the economic importance of livestock especially small ruminants (sheep and goats) in mixed farming systems is now receiving attention. In small holder production systems, sheep and goats are important because they require less initial capital and maintenance costs; are able to use marginal land and crop residues; produce meat and milk in readily usable quantities; easily cared for by most family members; are prolific and require only short periods to increase flock sizes after natural disasters such as drought or as a result of increased demand and market prices. The rate of return on investment under good management is high (35%) for goats and 55% for sheep (Lamorde, 1993). Furthermore, small ruminants compete well with other livestock in quality of meat produced. In addition, they play an important role in the welfare of the smallholder arable farmer in Nigeria through the income generated when sold. Also, with the increasing frequency of droughts and boom and bust pattern in the cattle population, sheep and goats are playing a significant role in stabilizing households and providing them with a means of recovery after droughts (Peacock, 1983). Thus, their importance in small holder farming systems is rapidly increasing. Small ruminants produce about twice as much meat per animal unit in the tropics than cattle (Egahi *et al*., 2012).

In sub-Saharan Africa, sheep provide almost 30% of the meat consumed and around 16% of the milk produced (Lamorde, 1993). Sheep contribute about 50% of the total domestically produced meat in Nigeria (Lamorde, 1993). Sheep are ruminant animals that have a modified gut that allow them to digest cellulose. They thrive in a wide variety of environments in the tropics and sub-tropics. Globally, sheep rearing is predominantly aimed at wool production but in many countries, meat is the major product (Croston and Pallot, 1994). Nuru (1985) stated that in Nigeria, sheep play significant role in the socio-economic life of rural and poor resource farmers. They contribute to the nutrition of people producing protein of high biological value to the populace and are kept as source of financial reserves for the farmers and insurance against crop failure. Sheep have a special function among the followers of Islam and are also used for funeral celebrations and dowries in Ghana (Koney, 2004).

Nigeria possesses about 41.3 million sheep (FMARD, 2016). It requires less capital as they can be completely maintained on pastures, browse, and agricultural waste products. A flock of sheep can provide families with food each day in the form of milk, but only in limited parts of the world are sheep milked for diary foods. Sheep milk is an excellent raw material for the milk processing industry especially in cheese production. The Mediterranean countries are the biggest producers of sheep milk. They participate with approximately 47% in the overall world production of sheep milk. (http://agriculturenigeria.com/farming-production/livestock/sheep). Sheep milk yields 18 to 25 % cheese, whereas goat and cow milk only yield 9 to 10 %. (http://agriculturenigeria.com/farming-production/livestock/sheep). While sheep usually

produce less milk than goats and much less than cows, sheep milk sells for a significantly higher price per pound, almost four times the price of cow milk. (http://agriculturenigeria.com/farming-production/livestock/sheep).

2.4 Breeds of sheep in Nigeria

Several hundred breeds of sheep have been identified by FAO (Food and Agriculture Organization) of the United Nation, with the estimated number varying somewhat from time to time: About 863 breeds as at 1993 (Maijala, 1997), 1314 breeds as at 1995 (Scherf, 2000) and 1229 breeds as at 2006 (FAO, 2007). These numbers exclude extinct breeds, which are also enliste by FAO. However, in Nigeria there are four breeds of sheep: The West African Dwarf, Yankasa, Uda and Balami.

2.4.1 Yankasa

Yankasa **(**Hausa, White Fulani,Yankasa) is the most widely distributed being found all over the country (Adu and Ngere, 1979). The Yankasa is a medium sized breed of sheep. The tail is long and thin, the ears moderately long and somewhat droopy (Mason, 1996). Rams have curved horns and a hairy white mane and ewes are polled (Mason, 1996). Yankasa have white coat colour with black patches around the eyes, ears and muzzle, the rams stand 70 to 80 cm at the withers and weigh 55 to 60kg at maturity (Mason, 1996). Mature females could weigh 25 to 40kg while male weighs between 35 and 50kg (Mason, 1996). The milk yield in kilograms per lactation is between 30 and 56kg and has a lactation length of 91 days (Mason, 1996). The milk yield is 960 grams per day (Mason, 1996).

2.4.2 Uda

The Uda is also known as Bororo and North Nigerian Fulani (Mason, 1996). The Uda is found in Northern Nigeria, Southern Niger, central Chad, Northern Cameroon and Western Sudan (Mason, 1996). It is one of the hair sheep breeds of the Sahel type. It is also a meat breed. It is a long legged breed of sheep with distinctive coat colour of brown or black anterior and white posterior (Ngere *et al*., 1979). They are large with straight and long face (Mason, 1996). The rams of the Uda are horned and the ewes are usually polled (Mason, 1996). The Uda is slightly smaller bodied than the Balami, although their size ranges overlap and the weight of mature females could be 30 to 40kg while mature rams weigh 30 to 60kg (Mason, 1996). Milk yield per lactation lies between 32 and 36kg for an average lactation length of 91 days (Mason, 1996).

2.4.3 Balami

Balami sheep is the largest indigenous breeds of sheep in Nigeria (*Buvanendran and Adu, 1990).* As a pastoral animal, it is confined to the semi-arid north but it is favoured as a stall fed breed by Muslims throughout the Nigerian middle belt. It is white and hairy with pendulous ears, long leg and a long thin tail (Mason, 1996). Rams are horned but ewes are normally polled. Another feature that makes the Balami distinctly recognizable is its Roman, bulbous nose that distinguishes it from the Yankasa (Mason, 1996). It has good potential as a meat producer. The weight of mature males ranges from 40 to 80kg while that of female lies between 30 and 40kg. The milk yield per lactation lies between 28 and 33kg in 70days (Mason, 1996).

2.4.4 West African Dwarf sheep

The West African dwarf is the predominant breed of the humid tropics from southern West Africa through central Africa (Mason, 1996). The West African Dwarf is a small bodied, compact breed which may be all white, black, brown or spotted black or brown on a white coat (Mason, 1996). Its variation in colour and patchy distribution makes it difficult to distinguish it clearly from the Yankasa rams. Its weight is approximately 37 kg (Mason, 1996). Rams have a well-developed throat ruff and are horned while the ewes have mature weights of 25 kg and are usually polled (Mason, 1996). Yankasa sheep tend to have a short lambing interval and can be bred at the age of 7 to 8 months (Mason, 1996). The prolificacy of adult ewes is low to moderate and it ranges from 1.15 to 1.50 lambs per lambing. This breed is also trypano-tolerant (tolerant to trypanosomiasis disease) (Mason, 1996).

2.5 Feed resources for small ruminant production in Nigeria

The cardinal principle behind successful livestock development programme of any nation is the availability of suitable animal feed resources. Nigeria is endowed with these resources, but not yet fully exploited (Lamorde, 1993). In developing countries the major feed resource for ruminant animals is the pasture (Fadiyimu *et al*., 2015). The feed resources available for small ruminants are natural pastures, browses and crop residues and by-products. The availability and quality of these resources vary, but evidence is presented to show that when they are properly selected and combined according to their nutritional characteristics, adequate and productive diets could be provided all year round, for sustainable small-ruminant production and productivity. Pasture development,

hay and silage, making of concentrates using available grains and tubers, utilization of crop residues and agro-allied by-products, all would go a long way in aiding the development of livestock in Nigeria.

Livestock feed may be defined as any dietary substance that nourishes the animal's body for maintenance and reproduction. These feeds are either roughages (forages) or concentrates (Lamorde, 1993). According to Lakpini (2002), feeds are substances voluntarily taken in by animals to provide nutrients such as energy, protein, mineral and vitamin metabolized in the body to maintain the body, produce body tissue, fluids and by-products such as meat, milk and eggs. Most feeds are natural substances which most commonly are organic matter with little component of inorganic matter. Feed is in very short supply and of poor quality (Tanko, 1993). The author further stated that most range lands grazed by these livestock in the sub-humid, to the dry savannas produce less than 1 tonne DM/ha and contain crude protein of 9% to 8% only during the early and mid-wet season. According to Isah, *et al*. (2015), in developing countries like Nigeria, livestock are fed mainly on low quality roughages, including natural grazing and agro-industrial by-products, all of which contain large quantities of lignocellulosic material. These feeds are deficient in protein, energy, minerals and vitamins. In addition, at certain times of the year, the quality of grazing and browse deteriorates substantially due to seasonal influences, and livestock productivity consequently declines.

The productivity of the natural range cannot support optimum performance of animal all year round due to short rainy season (less than 750mm per annum) (Ruthenberg, 1980).

The seasonality of feed supply in northern Nigeria has adversely affected animal production (FDLPCS, 1992). For greater part of the year, grasslands in the tropics do not supply sufficient nutrients in stocks for adequate productivity (Otchere *et al*., 1977). African pastoralists are highly dependent on crop residues from their own small plantings or from crop farms to supplement grazing during the dry season. McDowell (1985) reported that in northern Nigeria, grazing normally provides sufficient energy from June to October but grazing cannot meet the animals' energy needs from December through May resulting in serious weight losses. Crop residues have been reported to play very significant role in supplementing for the shortfall (Raay and De Leeuw, 1975) during the early part of the dry season. The crop residues are made up mainly by cereal stover, which are mostly low in nutritional quality, grain legume haulms, which are valuable feed resources due to their higher crude protein content 12 to 20% and digestibility (60 to 80%) as reported by Tanko *et al*. (1990); Larbi *et al*. (1999) and Omokanye *et al*. (2001). Large quantities of legumes (cowpea shells and groundnut haulms) and cereal crop residues are produced annually and can be used as cheap sources of protein and energy in growing sheep. According to Stanforth (1979), poor quality roughages (forages and crop residues) which are high in fibre and low in nitrogen, energy and minerals are often the feed available to sheep and goats in Nigeria particularly during the late dry season (March-May). Agricultural by-products and crop residues are also used for fattening and dry season feeding of small ruminants (Ademosun *et al*., 1988). Low digestibility associated with low nitrogen content of the feed limits intake and animals on these diets alone are often in negative energy and nitrogen balance (Paulino *et al.*, 2008). It is

therefore essential that these deficiencies are corrected when crop residues and agricultural by-products are used as feeds.

2.5.1 Forage resources

Forages are the single most important feed source for ruminants worldwide (Wilkins, 2000). They are edible parts of plants, other than separated grain, usually with substantial contents of cell walls (Wilkins, 2000). Forages are suited to utilization by herbivores that have a capacity for microbial digestion of cell wall constituents (Wilkins, 2000). According to Babayemi *et al*. (2014) forages are plants that are cultivated for their vegetative portions and are used in fresh or preserved forms for feeding livestock. Forage is the major nutritional resource for ruminants particularly in sub-Saharan African countries (Akinsoyinu and Onwuka, 1988) and most of the forages that provide animal nutrition are supplied by the natural vegetation and generally referred to as natural pastures. The semi-arid ecological zone of Nigeria has the lowest forage resources, yet is hosting over 90% of the cattle and 70% sheep and goats population (RIM, 1992). The zone is characterized with sporadic year round shortage in the supply of pasture both in quality and quantity despite the abundant supply during the late rainy and early dry season; and livestock farmers experience a shortage of forage for feeding livestock (Muhammad *et al*., 2008). Natural pastures or rangelands are the cheapest form of ruminant feeds available in Nigeria. However, it has been observed that natural pasture species in the tropical countries are of low quality (Henzell and Mnnetje, 1980) and barely satisfy the nutritional requirements for maintenance of animals (Mohamed-Salem, 1994). Natural pastures are the main source of minerals but do not satisfy all the minerals required by livestock (Miles and McDowell, 1983). Good quality forage

generally provides adequate protein for mature sheep (Nyako, *et al*., 2015). Gamba (*Andropogon gayanus*), one of the high-yielding grass species in West Africa, has been found to be palatable and nutritive at lush stage of growth and are well accepted by ruminants throughout the year under moderate grazing pressures, but becomes coarse and fibrous if under-grazed. Its nutritional value is moderate in young growth (CP 7-10%) and (about 18% CP) in fertile soils (Schultze-Kraft, 1992). Feed value decreases rapidly after flowering, and so conserved feed materials is often of little nutritional value.

Fodder trees and shrubs constitute a vital component in livestock production in the arid and semi-arid tropical zones of Africa where about 52% cattle, 57% sheep, 65% goats and numerous camels are found (Dicko and Sikena, 2003). The excess of pasture produced during the rainy season is conserved for redistribution over the year. Hay and silage making are the two conventional forage conservation methods. There are inherent difficulties in conservation of forage as hay (Amodu *et al.,* 2008); the right time climate suited for hay making coincide with the time when forages are of low quality while making of good quality hay during the rainy season when they are of optimum nutrient concentration is practically impossible due to humid condition (Kallah *et al*., 1997). Ensiling offers alternative means of fodder conservation during the rainy season while retaining nutrient quality of the forage. Silage production however, is not a common practice among the majority of livestock producers in Nigeria, but a viable option for succulent feed conservation for use during the dry season. According to Ibahze *et al.* (2015), silage making is an important tool for farmers in preservation of surplus feed during the wet season in ensuring all year round availability of feed. Ensiling is the

preservation of forages, crop residues and by-products based on lactic acid fermentation under anaerobic condition. The lactic acid bacteria ferment the plant sugars (Water Soluble Carbohydrates) in the crop to lactic acid (Mannatje, 1999). Smith *et al*. (1979) reported that among the numerous methods of processing poor quality feedstuff, ensiling is considered the most economical process. Browse plants can improve the total supply of feed given to ruminants; it can improve the quality of the feed and can also compensate for seasonal fluctuations (Smith *et al*., 1979). Browse species are locally perennial sources of feed, rich in protein and minerals that are particularly appropriate for small ruminants (Norton, 1994). Trees and browse legume forages are rich in most essential nutrients such as proteins and minerals and tend to be more digestible than grasses and crop residues (Carew *et al.,* 1989). A large numbers of trees and herbaceous legume leaves have been found to meet the nutrient requirement of small ruminants (Devendra, 1971). Leaves from browse plants and fodder crops form a major part of livestock feed in tropical countries, (Mandal, 1997) and play an important role in improving dietary protein (Aregheore *et al.,* 1998; Kaitho *et al*., 1998) as a supplementary feed. A study carried out by ILCA in Nigeria, established that the use of *Leucaena and Gliricidia* as supplementary feeds significantly increased the growth and survival rates of lambs (Atta-Krah and Reynolds, 1989). Daily feed intake has been reported to increase when sheep and goats were supplemented with leguminous browses (Amodu and Otaru, 2004). Browse plants have been reported to have been fed to sheep and goats as they form a good substitute for grass during prolonged period of drought to check the seasonal fluctuation in feed resulting in improved animal performance (Garba and Ado, 2015).

2.5.1.1 Grass forages

Pasture grasses, mainly C4-plants frequently contain crude protein levels of 8% or less, which are inadequate for animal production (Humphreys, 1991). During the dry season, there is a drastic decrease in the nutritional quality of tropical grasses, which is reflected by low crude protein (CP) and increased lignin content in the cell wall (Paulino *et al.*, 2008). The limited CP availability provides the critical threshold for adequate microbial growth on the fibrous carbohydrates in basal forage (Lazzarini *et al*., 2009). This CP deficiency implies poor utilisation of potentially degradable cell wall by microorganisms and results in decreased intake and animal performance (Paulino *et al*., 2008). Gamba grass grows well on infertile, acid soils in hot climates and in a wide range of climates, but is particularly useful in areas with a long dry season. Gamba grass stays green long into the dry season when most other grasses are already dry, is easy to cut and can tolerate grazing. Gamba provides palatable forage when young but feeding value declines rapidly with age and decreasing leaf/stem ratio (Amole *et al*., 2015). Mineral content is low (0.08 P and 0.27 Ca in DM) (Ajiji *et al*., 2013). Agishi (1985) reported that gamba grass is available in abundance in almost all ecological zones in Nigeria. The problem with gamba, like other tropical grasses, is the rapid decline in crude protein and soluble carbohydrate with age (Amole *et al*., 2015). This is coupled with a progressive increase in crude fibre and lignin (Agishi 1985; de Leeuw 1979). Of the pasture grass species, only *Andropogon gayanus* is well adapted to a wide range of relevant environmental conditions. It grows reasonably well in both the wet season and long into the dry season (Phengsavanh, 1997).

2.5.2 Agro-industrial by-products

The use of agro-industrial by-products as feed is an alternative method of overcoming shortages and higher prices of conventional feeds in ruminant nutrition. Many by-products have substantial nutritive value as animal feed. Thus cereals can be largely replaced by these by-products and therefore competition between human and animal for nutrition is less. Furthermore, using these by-products in animal nutrition can solve related environmental problem (Mirzaei-Aghsaghali and Maheri-Sis *et al*., 2008). The use of kitchen waste, industrial waste, agro-by-products and crop residues are comparatively cheaper than conventional feeds, particularly soon after harvest. Some of the agro-industrial by product of importance in Nigeria include: Groundnut cake, Cotton seed cake, Beniseed cake, Castor seed cake, Palm kernel cake, Brewer dry grain, Molasses, Brewers spent grain, Rice bran, Maize offal, Wheat bran, etc (Onyeonagu and Njoku, 2010). The use of crop residues and agro industrial by-products as supplement is becoming increasingly popular in Nigeria. Agro-industrial by-products in Nigeria vary from primary processing of farm produce wastes to wastes from agro-allied industries. Some wastes are left unutilized, often causing pollution and hazard. Those that are utilized do not have their full potentials harnessed (Devendra, 1982). Pagot (1992) reported that agro-industrial by-products have high nutrient content to sustain ruminant animals despite their high fibre level. Tegbe *et al*. (1995) indicated that except for rice offals and cassava root peels, the crude protein content of most agro-industrial by-products are higher than that of maize. The suitability of grain offal (dusa) and crop residues in feeding ruminants is also well documented (Ahamefule *et al*., 2002 and Anigbogu, 2005). In Nigeria, large quantities of agro-industrial by-products are produced

and many of them have potentials as non-conventional feedstuffs (Adeniji and Ehimere, 2003). Such by-products include corncobs, cassava peels and brewers' grain. Brewers' spent grains, the by-product of the grains fermented during beer making process have been used as feedstuffs for both ruminants and monogastric animals (Ekanem, 2012) and is considered to be a good source of un-degradable protein and water soluble vitamins which stimulate appetite and feed intake (Tolkamp, 1988).

2.5.3 Crop residues forages

Crop residues usually consist of the above ground part of cereal plants after grain removal. They are potentially rich sources of energy, because up to 80 % of their dry matter consists of polysaccharides (Meng, 2002). Cell walls of crop residues consist mainly of polysaccharides, protein and lignin (Meng, 2002). These substances, with small amounts of other components, like acetyl groups and phenols, are organized in a complex three-dimensional structure (Meng, 2002). Other wall components include suberin, cutin, tannins, waxes and minerals (Meng, 2002).

The term crop residue generally refers to various by-products from crop cultivation. Each residue, and even each fraction of certain residues, is different in terms of its availability, its nutritive value and its potential impact in relation to the overall feeding system. The fibrous crop residues have high biomass with low crude protein and high crude fibre contents, of approximately 3-4% and 35-48% respectively (Devendra, 1997). 'Crop residues' has become the used term in tropical research and development circles for describing the fibrous by-products of cereals, sugarcane, roots and tubers, pulses, oilseeds, oil plants, vegetables and fruits (Owen and Jayasuriya, 1989). Ahmed and

Kibon (2015) stated that crop residues are post harvest roughages after harvesting and threshing the cereal crops. They include the residues made up of stalks, husks and cobs from maize, sorghum, millet, rice, wheat, sugarcane etc. The authors further stated that residues are also obtained from legume crops such as groundnuts, cowpeas, soybeans and other leguminous crops which include haulms, cowpea husks, groundnut pods and vines. Crop residues have been estimated to account for about 25 % of the total feed energy suitable for ruminant livestock in both developed and developing countries (Kossila, 1985). Tchinda *et al*. (1993) reported native pasture and crop residues to be the most widely available low-cost feeds for ruminants in the tropics. Crop residues are potentially rich sources of energy as about 80% of their DM consists of polysaccharide but usually underutilized because of their low digestibility, which limits feed intake (FAO, 2002). According to Tanko (1993), feed is in very short supply and of poor quality. The author further stated that most range lands grazed by these livestock in the sub-humid, to the dry savannas produce less than 1 tonne DM/ha and contain crude protein of 9% to 8% only during the early and mid-wet season. Stanforth (1979) reported that, poor quality roughages (forages and crop residues) which are high in fibre and low in nitrogen, metabolizable energy and minerals are often the feed available to sheep and goats in Nigeria particularly during the late dry season (March-May).

Crop residues have been reported to play very significant role in supplementing for the shortfall (Raay and de Leeuw, 1975) during the early part of the dry season. The crop residues are made up mainly by cereal stover, which are mostly low in nutritional quality, grain legume haulms, which are valuable feed resources due to their higher crude protein

content 12 to 20% and digestibility (60 to 80%) as reported by Larbi *et al*. (1999) and Omokanye *et al*. (2001).

Cereal straws are produced in considerable quantities in many countries representing the most widely underutilized source of carbohydrates. Intake may be increased, about 20% by chopping the residue (Males, 1987). With supplement, intake of residues may increase from 20 to 30% (Males, 1987). Variations in the proximate analysis of different unconventional feeds were reported by various authors. According to Hamzat *et al*. (2007), variation occurred in the physical, biological and nutritional properties of the different sources.

2.5.4 Nutritive value of crop residue

Nutritive value is generally determined by feed composition, intake and utilization efficiency of digested matter. Thus, the value of a feed depends on chemical composition, digestibility, intake and efficiency (Meng, 2002). Cereal crop residues are deficient in nitrogen and have high cell-wall content, which reduce their intake and digestibility (Jess and Michael, 1989). It is necessary to study the factors that limit energy intake from cereal crop residues, because large increases in animal productivity can be achieved by relatively small increases in digestibility and intake (Ranjhan, 1997). The limited use of cereal straws is due to their low voluntary intake and low digestibility, associated with high lignin content, the manner in which this indigestible material is bound to the digestible cellulose and hemicellulose, and the low nitrogen concentration (Sundstol and Coxworth, 1984). Crop residues are known to have low content of available protein, energy and minerals (Doyle *et al*., 1986 Tagel-Din *et al*., 1989). Ruminants prefer

feedstuffs relatively rich in crude fibre (Williamson and Payne, 1987). Mahadevan (1983) estimated that in quantitative terms, crop residues can supply a substantial part of the maintenance requirements of all ruminants.

2.6 Factors affecting the nutritive value of crop residues

A variety of factors have been identified that may influence the nutritive value of crop residues. These factors can be divided into three categories namely: plant, animal and environmental.

2.6.1 Plant factor

The lignin fraction and associated phenolic compounds are factors most consistently associated with the rigid structure of plants and limited accessibility (Meng, 2002). The association of lignin with cell wall polysaccharides is also believed to be responsible for resistance of plant cell walls to microbial digestion in the rumen (Meng, 2002). The author further reported that other plant factors which include: species, stage of maturity at harvest, cultivar, and proportions of leaf, sheath and stem are believed to influence the nutritive value of crop residues. As plants mature, nutrient digestibility generally declines, linked to a decrease in the digestibility of cell wall components (Meng, 2002). Xing (1995) reported that, at an early growth stage, *in vitro* DM digestibility (IVDMD) of wheat straw is pretty high. As wheat matures, however, the IVDMD of straw progressively decreases. When the grain is completely mature at harvest, the straw has its lowest IVDMD value, resulting from decreased nitrogen content and increased lignification. Xing (1995) also reported a variation in chemical composition and digestibility of crop residues among cultivars. Another large variation in chemical composition and digestibility is found among straw fractions. Research data from Xing

(1995) showed that stems from wheat straw have a much lower organic matter (OM) digestibility, compared with leaf blades and sheathes. This low digestibility can be attributed to their high content of NDF and lignin. In rice straw, the OM digestibility of stems is much higher than that of leaf sheathes and blades. Similar results were also reported by Aman and Nordvist (1983).

2.6.2 Animal factors

Little information is available about animal factors that influence the nutritive value of crop residues. Farmers in China have long known that different breeds and types of animals use crop residues with various efficiencies (Meng, 2002). Cattle, which retain fibrous matter in the rumen slightly longer than sheep or goats, presumably have an advantage with lower quality crop residues (Meng, 2002). Cross-bred Brahman (*Bos indicus*) steers, when fed hay with 730 g/kg NDF, digested more NDF in the rumen and had longer ruminal retention time for lignin than did Hereford (*Bostaurus*) steers (Kennedy, 1982). With increasing popularity of cross-breeding techniques in China, farmers noted that, on a high concentrate diet basis, hybrid beef steers have much better growth performance than do native breeds; in contrast, on a low-quality fibrous feed, the contrary was observed (Meng, 2002). Although the exact mechanism of this difference in animal performance between hybrid and native breeds is unclear, an inherent difference in food intake and digestion capacity may be responsible.

2.6.3 Environmental factors

Some environmental factors, including location, climate, soil fertility and soil type, seem to influence the nutritive value of crop residues (Meng, 2002). Recent studies

(Xing, 1995) have indicated that there can be significant differences in chemical composition and digestibility of crop residues from crops grown on different soil types. Irrespective of crop cultivar, straw from wheat grown in the so-called tide soils (alluvial soils with diurnal variation in groundwater level) had considerably higher CP content and lower fibre (NDF, ADF and ADL) content than straw from drab soils (cinammon soils of forest origin) (Meng, 2002). These are probably the cause of digestibility differences.

2.7 Methods of improving the nutritive quality of cereal crop residues

Ruminants despite their unique and highly efficient digestive system are not able to extract sufficient energy to grow and produce milk from low quality or highly lignified residues (Meng, 2002). These must be properly processed or treated in some way to make them useful for production. Feeding crop residues limit ruminant productivity by lowering intake because they hinder ruminal functions (Sarwar *et al*., 2004). In order to improve the intake and digestibility of low quality crop residues, physical and chemical treatments have been explored. These treatments disrupt the cell wall by dissolving hemicelluloses, lignin and silica, hydrolyzing uronic acid and acetic acid, esters and swelling cellulose (Jackson, 1977). These processes may improve the digestibility of the treated materials and the net yield of available dry matter (Doyle *et al*., 1986). Several treatments have been applied to try to increase intake and digestibility of cereal straws; perhaps the most widely used treatments are chopping the straw, addition of ammonia or urea nitrogen (Adu *et al.*, 1990), anaerobic in-silo fermentation, treatment with ammonium hydroxide (Diarra, 1983) and supplementation with concentrates (Huston *et al.*, 1988), or with good quality hay (Zan, 1989).

Results of cereal straw treatment with urea nitrogen appear to vary greatly. According to Smith *et al*. (1979) nutritional value of poor quality feedstuffs can be increased by the following methods: ensiling, dehydration, single cell protein production, pelleting, deep stacking, chemical enhancement of digestibility; ensiling is considered the most economical process. At present, the main treatment methods of forages such as cereal straws are either mechanical e.g grinding), physical (e.g. temperature and pressure treatment) or a range of chemical treatments of which sodium hydroxide or ammonia are among the more successful (Greenhalgh, 1984). Ibrahim (1981) summarized the various methods of improving the nutritive value of fibrous residues as shown in figure 1.

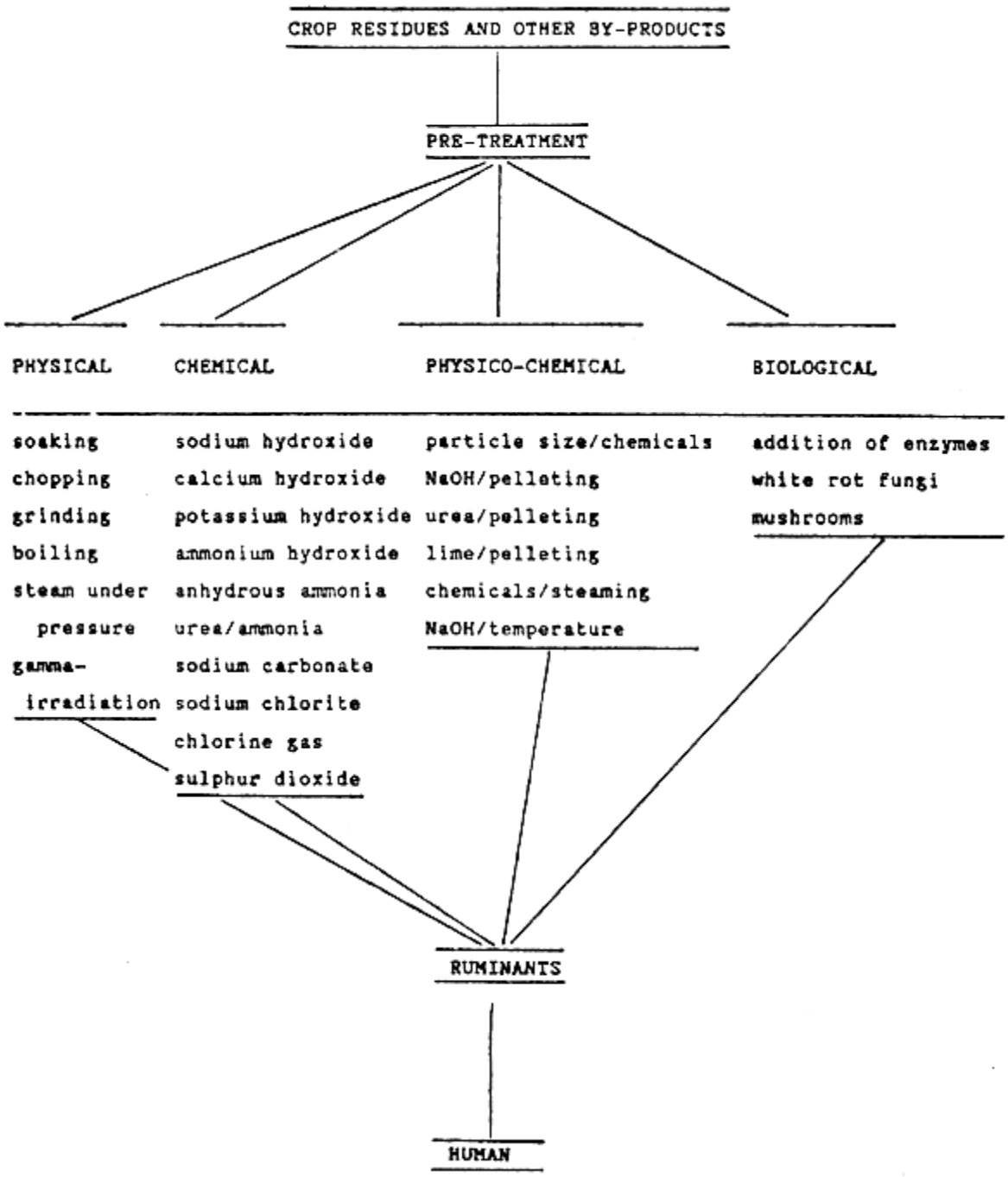


Figure 1: Methods of improving the nutritive value of fibrous residues (Source: Ibrahim 1981)

2.7.1 Physical treatment

Physical treatments of crop residue have received an appreciable amount of research. Crop residues can be ground, soaked, pelleted or chopped to reduce particle size or can be treated with steam and/ pressure or X-rays (Emtenan *et al.,* 2012). Chopping and grinding rice straw may reduce time of passage in the rumen and improve feed intake (Doyle *et al*., 1986). Grinding increases the voluntary intake of straw with or without an increase in digestibility, but it often leads to an increase in digestible energy (DE) intake. Jackson (1977) quoted an increase of up to 30% in DE by grinding. Many of these treatments are not practical for use on small-scale farms as they require machines or industrial processing (Schiere and Ibrahim, 1989). However, small machines to grind or chop rice straw maybe feasible (Schiere and Ibrahim, 1989). It was reported that the use of steam treatment in a high pressure vessel at different pressures and for a range of different treatment times increased the rate of *in vitro* degradation in the rumen fluid after 24h but could not enhance the potential degradability of the fibrous fractions, neutral detergent fibre (NDF), acid detergent fibre (ADF) and hemicelluloses (Liu *et al.*, 1999). Of the methods available for physical processing, grinding has given reasonable results when roughages are included in complete diets (Swan and Clark, 1974).

2.7.2 Heat and pressure treatments

Steam and /pressure treatment of straw is another promising method to improve the quality of cellulosic feedstuffs for animals by solubilization of cellulose and hemicellulose and/or by freeing digestible materials from lignin or silica (Horton *et al*., 1991). By applying the steam explosion process, Kling *et al*. (1987) demonstrated that about 60% of the hemicellulose fraction in the sugarcane bagasse was hydrolyzed and

further, the susceptibility of cellulose to enzymatic hydrolysis increased. Steam pressure without ammonia increases acidity and promotes solubilization of hemicelluloses. The increases in acidity come partly from the release of acetyl groups in the hemicellulose and are likely an explanation of some of the increased digestibility (Bacon *et al*., 1981). Increases in digestibility are in the same range as for ammonia treatments (Van Soest., 2006).

2.7.3 Biological treatment

Ruminant animals in many tropical countries subsist mainly on crop residue based diets (Mahesh and Madhu, 2013). The increasing expansion of agro-industrial activity over the last few years has led to the accumulation of a large quantity of lignocellulosic residues all over the world (Mahesh and Madhu, 2013). Although a vast energy potential is locked in these lignocellulosic crop residues (Jung, 1989), these are not utilized to their fullest potential for ruminant feeding due to poor digestibility, low nitrogen and mineral contents which rendered them to be classified under non-maintenance type of feeds. Recently, the biological treatments of crop residues to improve the accessibility of cellulosic fractions, thus improving their digestibility and feeding value have been attracting extensive interests among researchers (Yu *et al*., 2009). The major obstruction in biological conversion of lignocelluloses is the physical protection of cellulose by lignin against cellulo-lytic enzymes (Mahesh and Madhu, 2013). The potential of biological treatments has been explained by the ability of certain microbes (specifically *basidiomycetes* fungi) to disrupt plant cell wall by partial breakdown of the lignin-carbohydrate complex (Keller *et al.*, 2003) thus improving their utilization in the rumen by increasing the availability of fermentable energy to ruminal microbes (Akin *et al.*,

1993). This way, *basidiomycetes* seems to be the most promising microorganisms for biological pre-treatment and among them the selective lignin degrading white rot fungi (WRF) holds immense importance (Yu *et al*., 2009) in enhancing the utilization of poor quality roughages for animal feeding. WRF such as *Phanerochaete chrysosporium*, *Pleurotus* sp., *Lentinus edodes*, *Coriolus versicolor*, *Phlebia* sp. and *Ceriporiopsis subvermispora* have largely been studied for their ability to ferment different crop residues (wheat straw, olive mill solid waste, oil palm fronds etc.) to produce improved animal feed (Okano *et al*., 2009; Hassim *et al*., 2012) *P. chrysosporium* fungi degrades lignin to the extent of 65 to 70% while others like *Ganoderma applanatum* and *Coriolus versicolor* degrade over 45% of lignin in lignocellulosic materials (Gupta *et al*., 1993). Thus, microbial conversion seems to be a practical and promising alternative for increasing the nutritional value of agro by-products by transforming them into animal feed and producing a value added product (Villas-Bôas *et al*., 2002). The ideal microorganism for upgrading lignocellulosics into animal feed should combine high ligninolytic capability with low degradation of cellulose and hemicelluloses.

2.7.4 Chemical treatment of crop residues and by-products

The use of chemicals to improve nutritive value of crop residues dated back to 1920s when the German scientist, Beckman, used sodium hydroxide to treat stacks of crop residues with consequent improvement in its digestibility (Owen and Jayasuriya, 1989). Since 1964, there has been a widespread renewal of interest in chemical treatment, particularly in the developing countries, which have the highest potential for crop residues as ruminant feed (Owen and Jayasuriya, 1989). Many chemicals have been used to enhance the digestibility and intake of roughages; the most common ones; sodium

hydroxide, ammonia, sodium bicarbonate, sodium sulphate, ammonium hydroxide, calcium hydroxide and potassium hydroxide (Sundstol *et al*., 1978). Among these chemicals sodium hydroxide has proven to be the most effective in improving digestibility but lacks nitrogen and less available (Sundstol *et al*., 1978). The use of alkali from treatments of crop residues was given less attention after mid 1970s due to high cost and increased environmental pollution. Instead, use of ammonia from urea or other sources has increased in popularity for crop residues treatment (Teshome, 2009).

Both *in vitro* and *in vivo*, sodium hydroxide has been used as the chemical reagent for treatment. Various levels of body weight increases have been recorded depending on the level of inclusion of the roughage in the diet. Pirie and Greenhalgh (1978) reported 0.7–1.2 kg gain in beef cattle fed diets containing 60% treated straw. Similarly, Jayasuriya *et al*. (1982a) showed that milk yield of Friesian cows can be increased by 26% by feeding diet containing 65% urea treated rice straw. The achievement of increase in digestibility and intake are diminished by some drawbacks such as high price of sodium hydroxide, the corrosive nature of the chemical and the necessity for protective equipment and trained personnel for application. This has made sodium hydroxide treatment unfavourable. Ammonia is an alternative to sodium hydroxide for treatment of crop residues (Jackson 1977; Sundstol *et al* 1978). It has been adopted in many European countries because it does not leave residual alkali like sodium hydroxide and it increases the nitrogen content of the material (Teshome, 2009).

2.7.5 Supplementation of crop residues and other by-products

Supplementary feeds should be given during the dry season in order for the animals not to lose weight (Ademosun *et al*., 1988). These supplementary feeds include agro-

industrial by-products (groundnut, coconut and palm kernel cakes), by-products of grain extraction (maize, rice, sorghum and millet), household wastes such as peels of cassava, cocoyam, yam and plantain and industrial by-products (brewers spent grains) (Ademosun *et al*., 1988). Supplementation with concentrates (Tagel-Din *et al.*, 1989) or with legume hay usually improve straw utilization (Adu *et al.*, 1990), although results may vary depending on the level of supplementation. High levels of supplementation with concentrates have caused intake of the straw to decrease (Adu *et al.*, 1990).

Apart from alleviating nutritional deficiencies, an ideal supplement should also maintain or increase intake of the basal dietary material (Ademosun *et al*., 1988). The supplement should increase the efficiency of utilization of nutrients leading to increased animal production. It is not always that a feed added to a basal diet acts as a true supplement (Ademosun *et al*., 1988). The authors further stated that instead of truly supplementing the nutrients in the basal diet, the added feed may substitute part of the nutrient supply. Tree fodder legumes such as *Glyricidia maculate* and *Leucaena leucocephala* have been found to be highly suitable as supplements for treated straw diets. They contain a relatively high content of undegraded dietary protein (UDP) compared to common protein supplements such as coconut oil meal (Jayasuriya *et al*., 1982b), which presumably supplies the extra amino acid requirement of the animal. Supplementation should be by way of small quantities of green forage, tree fodder legumes (*Glyricidia maculata, Leucaena leucocephala*), industrial by-products (tea waste, oil seed meals), non-protein nitrogen (poultry litter) and minerals (Orskov and Ryle 1990). A supplement of green legume forage obtained from shrubs, tree leaves or water plants may further

enhance the utilization of the straw by ruminants, although the need seems to be smaller for animals fed treated straw (Orskov and Ryle 1990). Supplementation with non-protein nitrogen or high protein feedstuffs may improve intake and digestibility, but cannot always compensate for other anti-nutritional factors, such as high fibre content and presence of phenolic compounds; Chesson and Orskov, 1984).

2.8 Rice straw or paddy straw

Rice straw is the vegetative part of the rice plant, cut at grain harvest or after. It may be burned and left on the field before the next ploughing, ploughed down as soil improver or used as a feed for livestock (Kadam *et al*., 2000).

2.8.1 Distribution

Rice (*Oryza sativa*, L) which belongs to the family *Poaceae* originates from Asia where it has been cultivated since 6500 BC and is now naturalized in most tropical and subtropical regions (Heuze and Tran, 2015). Rice grows from 53°N in China to 35°S in Australia (Heuze and Tran, 2015). Optimal growing conditions includes: 20-30°C daily average temperature, with night temperature of over 15°C; fertile, heavy soils, 6.5-7 pH (Heuze and Tran, 2015). The two distinct varieties are "Swamp rice", which is usually planted in stagnant water and requires about 200mm rainfall per month or an equivalent amount from irrigation, whereas "upland rice" requires less irrigation and 750 mm rainfall on a 3-4 months period and no dessication (Heuze and Tran, 2015). Rice is the world's second largest cereal crop producing large amounts of crop residue (Emtenan *et al*., 2012). USDA (2010) reported that rice is the most important food crop for half of the human race and is the world's most consumed cereal after wheat. More than half of the

world's population depends on rice for 80 % of its food caloric requirements (Braun, 2006). In Africa, rice production has increased dramatically between 1970 and 2007 by over 130 % (Braun, 2006).

2.8.2 Characteristics of rice straw

Chemical composition of rice straw varies between varieties and growing seasons (Shen *et al*., 1998). The quality of rice varies tremendously. Data collected from rice straw samples revealed that the crop protein varies from 2 to 7 % while the ADP varies from 41 to 56% on a dry matter basis (Daniel *et al*., 2002). According to the authors research has not been able to explain thoroughly the reasons for variability in the nutritive value of rice straw, but some of the important factors responsible for the the variability could due to difference between days of harvest and baling, nitrogen fertilization management and geographic locations of the rice fields in the rice growing regions. Research has shown that higher nitrogen fertilization of the rice plants, results in higher crude protein production in the straw (Daniel *et al*., 2000). Theander and Aman (1984) reported that rice straw contains a relatively high proportion of leaf (60%), compared to other cereal straws such as *Hordeum vulgare* barley (35%), *Avena sativa* oats (43%) and *Triticum aestivum* wheat (20-41%). According to Vadiveloo (2000) leaves of rice straw contain less NDF than the stems but more ash and acid-insoluble ash, resulting in a lower *in vitro* DM digestibility of the leaves (50-51%) compared to the stems (61%). Daniel *et al*. (2002) reported that the species of the plant, the agronomic practice used, soil and temperature and the stage of growth influence the chemical composition and palatability of straw. Tesfaye (1999) and Solomon (2004) reported that there is a considerable variation in the contents of crude protein and crude fibre.

2.8.3 Nutritive value of rice straw

Nutritive value of a given feed is generally determined by nutrient composition, intake and utilization, efficiency of digested matter, species of plant, stage of maturity at harvest, cultivars and leaf to stem ratio (FAO, 2000). The usefulness and nutritive value of crop residues can also be variable depending on the species of livestock to which it is offered. Cattle, which retain fibrous matter in the rumen slightly longer than sheep have presumable advantage with lower quality crop residues (FAO, 2000). In some rice plants, the stubble has been reported to be of higher nutritive value than the straw, yet intake of the straw by cattle still exceeds that of stubble (Wanapat and Kongpiroon, 1988). The leaf fraction of the straw is more acceptable than the more highly digestible stem fraction of the stubble (Wanapat and Kongpiroon, 1988). Nour (2003) reported that rice straw contains CP concentration ranging between 2.0 and 6.0%. According to the author, rice straw contains more silica (12-16%) and less lignin (6-7%) than other straws which contain 3-5% silica and 10-12% lignin. Silica is a mineral with no nutritive value. Sharma *et al*. (2012) stated that paddy straw has limited nutritive value (low crude protein and digestibility) and high silica content; it should be used only as replacement for part of the forage in a ration (Daniel *et al*., 2002). It should not be used as a complete ration. When straws are fed to ruminants, the primary limitations to production are low overall digestibility, slow rate of passage in the rumen, low propionate fermentation pattern in the rumen, and low contents of fermentable nitrogen and by-pass protein (Daniel *et al*., 2002).

2.9 Utilization of rice straw in ruminants

Rice straw is potentially an important energy feed for ruminants as it is rich in carbohydrates (Jung *et al*., 1993). The authors further stated that, the potential of rice straw as an energy source is limited because of its complex lignified cell wall structure, which shields the energy yielding nutrients from microbial degradation in the rumen. The utilization of rice straw can be increased, provided some measures are taken to modify the structure of its cell walls (Chenost and Kayouli, 1997). Heuze and Tran (2013) stated that rice straw can be treated in order to improve its nutritive value and that those treatments are designed to enhance feed intake or/and digestibility. They added that improving digestibility may be achieved through mechanical, chemical, heat and pressure treatments. Nisa *et al*. (2004) stated that enhancement of the nutritive value of dry roughages with physical, chemical or biological treatments have been the focus of research. Liu and Orskov (2000) stated that numerous methods of physical, chemical and biological treatments have been investigated including supplementation with other feedstuffs on components in order to improve the utilization of rice straw by ruminants. According to Smith *et al*. (1979) nutritional value of poor quality feed stuffs can be increased by the following methods which include: ensiling, dehydration, single cell protein production pelleting, deep stacking and chemical enhancement of digestibility; ensiling is considered the most economical process.

2.9.1 Voluntary intake of rice straw

Animal performance is the product of supply, nutrient concentration, intake, digestibility and metabolism (Martens, 1994). Voluntary intake and digestibility are of great importance in evaluating roughage quality. The metabolism regulating voluntary intake

of low quality feeds such as rice straw is still not fully understood (Sarnklong *et al*., 2010). The generally accepted theory of feed intake regulation for poor quality roughages is that the capacity of the rumen to process the feed is the major factor determining voluntary feed intake (Baile and Forbes, 1974). Pearce *et al*. (2014) stated that voluntary intake of highly digestible forages is controlled by metabolic factors or is linked to requirements for maintenance and production. In the case of poorly digestible materials, however, attention has been focused on physical control of intake, particularly distension of, and removal from, the reticulo-rumen (Pearce *et al*., 2014).

The kinetic features of digestion for straws with varying proportions of nutrients and for straws which are supplemented to provide limiting nutrients are variable. According to Devendra (1997), the main determinants of intake and degradability of rice straw depend on their morphological characteristics such as the proportion of the different plant parts (leaves and stems), the chemical components in their tissues, their relative amounts of cell contents and cell walls and the physical and chemical nature of the cell walls. These influence the chewing behavior of animals and the extent of fragmentation in the reticulo-rumen (Sarnklong *et al*., 2010). Supplementation of a ration of rice straw with protein, energy and / or minerals may optimize rumen function also maximizing utilization of the rice straw and increasing intake (Sarnklong *et al*., 2010). Different supplementations can be used, such as concentrates, molasses, multi-nutrient blocks, green leaves, crop residues and locally available by-products (Sarnklong *et al*., 2010). Straw intake and digestibility in ruminants are influenced by straw characteristics (including chemical composition, morphological and anatomical features, physical nature and palatability); by feeding

conditions (including the amount offered and the frequency of feeding); and by animal characteristics (including species/genotype, live weight, age, body condition, type and level of production and disease) (Pearce *et al.,* 2014). The authors further stated that extremes of temperature and humidity and social interactions between animals may also affect intake. Eating rate has been used to evaluate herbage quality (Pearce *et al*., 2014). With wheat straw, material with a high proportion of stem is eaten much more slowly than leafy material (Pearce *et al*., 2014).

Habituation is also a factor, because straws that are eaten relatively slowly in early tests may be eaten more quickly in later tests. This occurred particularly with rice straws in which, it is believed, silica levels, may have affected acceptability initially (Hartley and Jones, 1978). The specific plant causes of such animal responses are unknown. The silica content of rice straw affects its palatability and hence the amount ruminants will eat. The limiting factors for utilization of rice straw by ruminants are low crude protein, high fibre and low available energy contents (Van Soest, and Jones (1968). According to Doble and Walker (1977), the utilization of rice straw as livestock feed is limited due to its poor palatability and low digestibility. Some studies have shown that high silica and lignin contents of the rice straw impede digestion by ruminants (Hartley and Jones, 1978). Rice straw is usually fed untreated without supplements in spite of the fact that many methods for improved utilization of rice straw have been developed and recommended (Sarwar *et al*., 2002). Because roughages remain in rumen longer due to high concentration of indigestible fibre and lignin, intake is reduced and thus impedes ruminant productivity (Sarwar *et al*., 2002). Preston (1985) reported that ammoniation usually decreases

digestibility by 5-10 % nitrogen content by 1-2 % DM and voluntary intake by as much as 50 % when offered free choice. Most data reviewed (Rehrahie, 2001; FAO, 2002) have shown decreased Nitrogen Detergent Fibre (NDF) and Acid Detergent Lignin (ADL), and a considerable increase in crude protein contents of the crop residues due to urea treatment.

The crude protein content of treated straw is always higher than untreated straw indicating the effectiveness of treatment (FAO, 2002). Fall *et al*. (1989) indicated that urea treatment improved intakes ($g/kgW^{0.75}$) from 48 to 61 with the corresponding improvement in digestibility (g/kg DM) from 428 to 545 for untreated and treated rice straw, respectively. Maximum use of straws as feed for ruminants depends on efficient fermentation by rumen microorganisms (Fall *et al*., 1989). Feeding rice straw should not exceed 25 %, but could be increased to 50 % if fed with supplement of feed having 14% crude protein or the entire ration with 2 pounds of tested liquid or block supplements (ANR, 2002). Dutta *et al*. (1990) reported higher digestibility coefficient of nutrients on urea treated rice straw based diet than those on untreated straw. Jackson (1977) reported that the crude protein content of the straw based diet could be increased by urea supplementation as urea is the cheapest source of nitrogen. The author further stated that urea treated straw contains higher crude protein than that of untreated straw.

2.9.2 Selection in relation to physical characteristics of rice straws

Weston (1985) included texture as a criterion governing acceptability of feeds and Hogan *et al.* (1986) suggested that animals select plant material on the basis of "tenderness." However, such characteristics are difficult to assess because, often, no one feature predominates and several factors interact (Sarnklong *et al*., 2010). In straws, such as

wheat and barley Wahed and Owen (1986) and Doyle *et al*. (1987) reported that animals usually show a preference for leaves rather than stems. In rice straw however, selection of leaves in preference to stems may not occur (Doyle *et al*, 1987), possibly because the leaf blades contain more silica than the stems (Van Soest, 1982).

2.10 Constraints to rice straw utilization

Several studies have been reported on the physical and chemical characterization and utilization of rice straw as ruminant feed (Vadiveloo, 2003). Rice straw consists of predominantly of cell walls, comprised of cellulose, hemicellulose and lignin (Sarnklog *et al*., 2010). To breakdown these components cellulase, hemicellulase and ligninase are required (Schiere and Ibrahim, 1989). These enzymes are not produced by the animals themselves but the reticulo-rumen of ruminants contains microorganisms that do produce cellulase and hemicellulase (Sarnklog *et al*., 2010). However, lignin cannot be broken down in the rumen due to the lack of ligninase (Sarnklog *et al*., 2010). Even if lignin could be degraded in the rumen it would not provide much energy for the animals (Sarnklog *et al*., 2010). Lignin however, has important effects on livestock production through effects on degradability and feed intake (Sarnklog *et al*., 2010). Han and Ha (1989) reported that rice straw is low in lignin (3-5 %) and contains 52-55 % cellulose and hemicellulose suggesting a potential source of energy for ruminants. The authors however stated that because rice straw is high in silica (9-15 %) and its structure is resistant to rumen microbial digestion, some chemical and physical treatments are necessary for maximum utilization as feedstuff. According to Jackson (1977) high fibre, lignin, silica and low crude protein and mineral status and low nitrogen contents of cereal straws are responsible for their low voluntary intake. With regard to forages, it has been

traditionally defined as the complex of dietary nutrients that are relatively resistant to digestion and are slowly and only partially degraded by herbivores (Chesson and Forsberg 1988). By this definition, fiber is composed of structural polysaccharides, wall proteins, and lignin. The main anti-quality role of lignin in forages is in limiting digestion of the structural polysaccharides cellulose and hemicellulose (Hatfield *et al.*, 1999). Lignification controls the amount of fiber that can be digested and, therefore, has a direct and often important impact on the digestible energy (DE) value of the forage (Jung and Allen 1995).

Lignification also influences the amount of dry matter that can be consumed by an animal (Mertens, 1994). The undigested portion of the forage passes slowly through the digestive system and contributes to the fill effect of the diet (Mertens, 1994). The greater the concentration of un-degradable fibre in the diet the less dry matter an animal can consume (Mertens, 1994). Therefore, lignifications impacts forage nutritive value by both decreasing DE concentration and limiting dry matter intake (Moore *et al*. 1993). It is an established fact that lignin concentration of forages is negatively correlated with digestibility (Jung and Deetz, 1993). The reason DM digestibility is negatively correlated with lignin concentration is because the concentration of lignin always increases as cell-wall concentration rises, and forage cell walls are always less digestible than cell soluble. Rice straw contains less lignin than other straws but has higher silica content. The leaves contain more silica than stems (Van Soest, 2006). Rice straws are more digestible than leaves because their silica content is lower, therefore the paddy crop should be cut as close to the ground as possible if the straw is to be fed to livestock (Jackson, 1977). Silica

is cell-wall bound or soluble. They are excreted in the urine and some calculi may occur but do not seem to be a serious problem. Silica and lignin in that order are the primary limiting factors in rice straw quality. Silicon is a nutrient element which has been overlooked largely because of its assumed inertness, but also because of its geochemical abundance that so greatly exceeds its metabolic use by plants and animals (Van Soest, 2006). Silica, one element of the rice cell walls can be present in high concentrations ranging from 5 % to 15 % depending on the rice variety (Vadiveloo, 1992) and the availability of this mineral in the soil (Agbagla- Dohnani *et al*; 2003). Silica reduces digestibility of rice straw in the rumen due to its direct action in preventing colonization by ruminal microorganisms (Bae *et al*; 1997; Agbagla-Dohnani *et al*., 2003). The role of silica on the quality of rice straw was also reviewed by VanSoest (2006) in an attempt to put into perspective the problems of silicon metabolisms. Furthermore, Heuze and Tran (2013) stated that excessive feeding of rice straw produces harmful effects, as it contains oxalic acid which binds the calcium in the diet.

Daniel *et al*. (2002) highlighted challenges in feeding rice straw which include poor palatability, low digestibility due to very high silica content (8-14 %) particularly true in the rice leaves which contains the highest levels of silica. The high silica level combined with other mineral compounds produces an average ash content of 17 % for rice straw. Low protein (2-7 %) CP and high oxalates rice straw differs from other straws in having a higher content of silica (12-16 versus 3-5 %) and a lower content of lignin (6-7 versus 10-18 %) whereas in all other straws lignin is the chief cause of low digestibility, in rice straw it is silica. The nutritive value of a feed is determined by (a) the concentration of

nutrients in the feed, (b) the amount eaten, (c) the proportion of the nutrients digested and (d) the efficiency with which absorbed nutrients are used (Pearce *et al.,* 2014). Data on all of these components are rarely available for cereal straws, and indices, such as chemical composition and digestibility values, are commonly used to assess nutritive value (Pearce *et al.,* 2014). Very few *in vivo* digestibility experiments have been conducted using cereal straw fed alone (without supplements) and most digestibility measurements are made *in vitro* (Pearce *et al.,* 2014).

Rice straw is low in nutritive value with low level of protein 2–5% DM), high fiber and lignin content (NDF>50 %), low DM digestibility (<65 %) thus resulting in low voluntary feed intake (1.5- 2.0 %) (Wanapat *et al*., 1985). Because of its low energy and protein content, the straw alone cannot support normal growth, causing a loss of body mass (Parnich, 1983). It should be used only as a replacement for part of the forage in a ration and not be used as a complete ration (Daniel *et al*., 2002). Studies have shown mixed results, depending on the quality of the straw and how it was used in the ration (Nader, 2000). Poorer animal performance has usually occurred when rice straw was the only feed. Rice straw contains high levels of oxalates (1-2 % DM) that are known to decrease calcium concentration and thus require calcium supplementation throughout the diet (Van Soest, 2006). Straws contain about 80 % of substances which are potentially digestible and are therefore sources of energy but actual digestibility by ruminants is only 45 to 50 % (Jackson, 2010). Furthermore, the amount an animal can eat is limited to less than 2 % of body weight because of slow rate at which it is fermented in the rumen (Jackson, 2010). For good growth on straw diets, a level of 8 to 10 % protein is needed

for young stock with subsequent improvement in consumption and energy intake (Jackson, 1979). The level of phosphorus in rice straw (0.02 to 0.16 %) is less than the level of about 0.3 % that animals need for growth and normal fertility (Jackson, 1979). A level of about 0.4 % calcium in the diet is usually considered adequate for livestock and many samples of rice straw have this amount, the range being from 0.25 to 0.55 % (Jackson, 1979).

Rice straw does not contain enough sugars, amino acids and minerals for efficient microbial growth, therefore feeding ruminants with only rice straw, without any supplement of other required nutrient sources will result in poor performance of the animals (Doyle *et al*., 1986). Animals fed un-supplemental straw diet will usually not gain any weight and very often will actually lose weight Sarnklog *et al.*, 2010). The combination of low intake, low degradability, low nitrogen content and an unbalanced mineral composition means that rice straw alone may not even meet the animals' maintenance needs (Sarnklog *et al.*, 2010). Poor degradability is caused by a series of factors (Schiere and Ibrahim, 1989). The fibre is very difficult to degrade which is partly an intrinsic characteristic of the straw fibre (Sarnklog *et al*., 2010). Biogenic silica, especially in the cuticle layer is a barrier to stop pathogens from attacking the plant tissue, including cellulose during rice growth (Daren *et al*., 1994) but also reduces the digestion of rice if harvested (Wilson, 1993). Among the trace elements affecting digestibility is silica, the content of which in rice straw varies between genotypes and according to growing conditions (Juliano, 1988).

Environmental factors such as location, climate, soil fertility and soil type have also been found to influence the nutritive value of crop residues (Van Soest, 1988). Digestibility of roughage is related to temperature, reflecting a negative correlation with increase in temperature in which high temperature increases the rate of enzymatic process associated with lignin biosynthesis promoting lignifications of cell wall and more rapid metabolic activity resulting in decreased pool of metabolites in the cell (Van Soest, 1988).

The quality of rice straw depends on many factors: variety, time between harvest and storage, nitrogen fertilization, plant maturity and weather conditions (Drake *et al*., 2002) The high level of lignification and silicification of the carbohydrate and the slow and limited ruminal degradation of the carbohydrate; as well as low content of nitrogen as the main deficiencies of rice straw affecting its value as feed for ruminants (VanSoest, 2006). The most widely used measure of the nutritive value of a feed is its digestibility (VanSoest, 2006). The digestibility of the leaf of rice is characteristically lower than the stem (Phang and Vadiveloo, 1992). As leaf comprises some 70% of whole straw (Vadiveloo, 1995), low leaf digestibility reduces the overall quality of rice straw and limits its use as an animal feed. Although digestibility is important, it is not the sole determinant of the nutritive value of a feed (Vadiveloo and Fadel, 1992). With low quality feeds, feed intake and compositional characteristics are also important (Madsen *et al*., 1997). Rice straw varies greatly in its feeding value with crude protein (CP) values from 2 to7% and acid detergent fibre (ADF) values from 46 to 56%. Some of the factors that may influence quality include days between grain harvest and baling, nitrogen fertilization, soil type and rice varieties, (Daniel *et al*., 2002)

2.11 Environmental impact of rice straw

Burning of straw causes atmospheric pollution and nutrient loss although it is a cost effective method for straw disposal. Also, it helps to reduce diseases that may occur due to re-infection from inoculum in the straw biomass (Keshtkar *et al*., 2007).When rice straw is burned or ploughed down, it may cause air pollution or leachates. Ploughing down will also propagates fungi (Kadam *et al*., 2000). Lemieux *et al*. (2004) stated that biomass burning has effect on global climate by emitting particulate matters and other gaseous pollutants. One tonne of rice straw burning releases 3 kg particulate matter, 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg SO_2 (Jenkins and Bhatnagar, 2003). Lung and respiratory diseases caused by burning adversely affect public health (Wang and Christopher, 2003). Pollutants emitted during biomass burning can produce significant changes in blood parameters as indicated by increased lymphocytosis, eosinophilia and neutrophilia in sheep (Ahmed *et al.*, 2003), oxidative stress (Rivero *et al*., 2005) as well as kidney (Uboh *et al*., 2010) and liver dysfunction in buffaloes (Massaguer *et al.*,2002). Biomass burning releases considerable amounts of some environmental toxicants which function as endocrine disruptors and integrity of reproductive function in mammals and ultimately contribute to infertility (Smith *et al*., 2007). Disappeared estrous activity, increased number of services per conception and high incidence of smooth ovaries with low progesterone level were evidenced in cross bred cows (Ahmed *et al*., 2003; Hozein, 2011) with impairment of reproductive health and adverse effects on fetal outcomes is increasingly recognized (Veras *et al*., 2009). Feeding rice straw to livestock is a way to reduce its environmental impact and to make it as an energy source and as a protein provider.

2.11.1 Rice straw as a source of organic manure

Rice straw is the only organic material available in significant quantities in most rice farms. About 40 % (N), 30-35 % of (P), 80- 85 % of (K) and 40 -50 % of (S) taken up by rice remains in vegetative plant parts at crop maturity (Emtenan *et al*., 2012). Straw is also an important source of micronutrients such as zinc (Zn) and the most important influence on the cumulative silicon (Si) balance in rice (Emtenan *et al*., 2012). Whereas mineral fertilizers are used and straw is incorporated, reserves of soil N, P, K and Si are maintained and may even be increased (Emtenan *et al*., 2012). Whereas S-free mineral fertilizers are used, straw may be an important source of S, thus, straw burning should not be practiced. In contrast, burning effectively transforms straw into a mineral K nutrient source and only a relatively small amount of K is lost in the process (Emtenan *et al*., 2012). Straw is removed from the field, burned in situ, piled or spread in the field, incorporated in the soil, or used as mulch for the following crop. Each of these measures has a different effect on overall nutrient balance and long-term soil fertility (Dobermann and Fairhurst, 2002). In areas where harvesting has been mechanized (e.g. Thailand, China and northern India), all the straw remains in the field and is rapidly burned in situ, therefore, losses of S, P and K are small (Keshtkar *et al*., 2007). In Indonesia and Philippines, straw is heaped into piles at threshing sites and burned after harvest. The ash is usually not spread on field and transferred from the periphery of the field to the center, or even from surrounding fields to the center field where the residues are burned. Over time, this practice results in the accumulation of nutrients (K, Si, Ca, Mg) in some parts of the field and nutrient depletion in other parts (Emtenan *et al*., 2012). Incorporation of straw and stubble into wet soil (during plowing) results in temporary immobilization of N

and a significant increase in methane (CH_4) emission from rice paddy, a practice that contributes to greenhouse gases (Emtenan *et al*., 2012). Incorporation of large amounts of fresh straw is either labour-intensive or requires suitable machinery for land preparation and may result in the build-up of disease problems (Emtenan *et al*., 2012). Transplanting should be carried out two to three weeks after straw incorporation (Emtenan *et al*., 2012).

2.12 Chemical treatment of rice straw

Chemicals used to improve the utilization of rice straw may be alkaline, acidic or oxidative agents. Among these, alkali agents have been most widely investigated and practically accepted for application on farms (Sarnklong *et al*., 2010). Basically, these alkali agents can be absorbed into the cell wall and chemically break down the ester bonds between lignin and hemicellulose and cellulose and physically make the structural fibers swollen (Chenost and Kayouli, 1997). These processes enable the rumen microorganisms to attack more easily the structural carbohydrates, enhancing degradability and palatability of the rice straw (Prasad *et al*., 1998; Selim *et al*., 2004). The most commonly used alkaline agents are sodium hydroxide (NaOH), ammonia (NH_3) and urea (Sarnklong *et al*., 2010). Since the beginning of the 19th century, attempts have been made to improve the digestibility and nutritive value of crop residues **(**Meng, 2002). The author reported that a major breakthrough was chemical treatment to remove encrusting substances (cellulose, hemicellulose and lignin).

Many chemicals have been screened in laboratory experiments for their potential to enhance digestibility of crop residues (Meng, 2002). However, only three are being

routinely used in animal research: sodium hydroxide (NaOH), ammonia (NH_3), and calcium hydroxide (CaOH) **(**Meng, 2002). Much emphasis has been put on straw upgrading techniques using treatment with chemicals (Owen and Jayasuriya 1989a), sodium hydroxide or ammonia in temperate countries and urea-ammonia in tropical countries. Treatment with these chemicals increases digestibility by 100 to 150 g DOM/kg DM and increases intake by about 4 g DM/kg live weight/day (25%) (Owen and Jayasuriya, 1989a).

2.12.1 Sodium hydroxide treatment

Several NaOH treatment methods to improve the use of crop residues for ruminant feeding have been developed by Jackson (1977) and Arieli (1997). The principal advantages of the different NaOH treatments are increased degradability and palatability of treated straw compared to untreated straw (Chaudhry and Miller, 1996). However the application of NaOH can be a cause of environmental pollution, resulting in a high content of sodium in the environment (Sundstol and Coxworth, 1984). NaOH treatment involves washing the straw after treatment and may cause water pollution. Sodium hydroxide treatment of crop residues has been investigated and used (Meng, 2002). The procedure basically followed the "dry method," where NaOH is applied at 3-5 % and the moisture content is 20-30 % of DM (Meng, 2002).

Alkali treatment may saponify the ester bonds between lignin and carbohydrates or the phenolic acid-carbohydrate complexes in plant cell wall (Meng, 2002). The author further stated that through these effects, structural carbohydrates in both lignified and unlignified plant tissues become more digestible, with consequent increase in rate and digestibility

(Meng, 2002). The treatment with NaOH results in increase in crop residue palatability and digestibility, and in animal performance (Xiong, 1986). Steers fed rations based on NaOH-treated wheat straw gained 20 percent faster than did the control group when concentrate was half of total ration (Sun, 1985). Ye *et al.* (1999) reported that dairy cows fed NaOH-treated rice straw diets ingested 1.9 kg (86.4 percent) more straw and produced 1.4 kg (7.9 percent) more milk per day than those on untreated-straw diets. Although NaOH treatment works effectively in improving the nutritive value of crop residues, NaOH is expensive, corrosive and its use may result in significant excretion of sodium ions in animal excreta (Meng, 2002). The author further reported that long-term accumulation of sodium may lead to soil fertility problems and environmental pollution.

2.12.2 Ammonia treatment of rice straw

Treatment of straw with anhydrous or aqueous ammonia (NH_3) or other ammonia releasing compounds has been widely investigated to improve degradability (Abou EL-Enin *et al*., 1999). Ammonia treatment not only increases the degradability of the straw, but also adds nitrogen (Abou-EL-Enin *et al*., 1999) and preserves the straw by inhibiting mould growth (Calzado and Rolz, 1990). Besides, ammonia treatment is an effective means of reducing the amount of supplemental nitrogen, reducing the costs of purchasing protein-rich feedstuffs and enhancing acceptability and voluntary intake of the treated straw by ruminants. The ammonia treatment slightly decreased NDF and increased ADF contents indicating that the cell wall properties were changed (Sanklong *et al*., 2010). Moreover, ammoniated rice straw is characterized by low physical strength, higher proportion of small feed particles with more attachment and growth of the rumen bacteria (Selim *et al*., 2002). The reduced particle size and the increased attachment sites could

lead to subsequent increased microbial colonization and digestion (Sanklong *et al*., 2010). Ammonia treatment increases feed value by making the cell wall more available for the rumen microorganisms and also the increased Nitrogen content improves microbial growth (Sanklong *et al*., 2010). Ngele *et al*. (2009) reported that the crude protein content in crop residues can be increased by ammoniation.

2.12.3 Lime (CaO)/Ca (OH)$_2$ treatment of rice straw

Lime (CaO)/Ca(OH)$_2$) has been thought of as a potential alkali for straw treatment since it is cheap and readily available (Sundstøl, 1985; Doyle *et al*., 1986). Calcium (Ca) residues, which remain in the treated straw, cause no serious problems to the animal or to the environment (Chaudhry, 1998). Research has already been carried out to examine effects of treatment with lime on the nutritive quality of cereal straw (Pradhan *et al*., 1997). Combinations of lime and urea may be attractive for straw treatment (Owen *et al* 1984; Sundstøl, 1985). Such a mixture would be able to combine treatment effects of both chemicals (Hadjipanayiotou 1984), together with the supplemental effects of the added Ca and nitrogen in the treated straw. In addition, mould inhibition is an important effect of ammonia released from urea from this mixture in moist straw (Zaman and Owen, 1995; Zaman *et al*., 1994; Pradhan *et al*., 1997). In such a combination neither the level of urea, and thus residual NH_3, nor Ca would be necessarily as high as if the chemicals were used alone **(**Nguyen *et al*., 2001). In addition, since the amount of urea can be reduced at the expense of a cheaper chemical (lime), the mixture would be more economical, as long as the overall treatment effect is maintained or enhanced **(**Nguyen *et al*., 2001). Moreover, the quality of animal excreta as fertilizer would be increased due to the residual N and Ca **(**Nguyen *et al*., 2001). Nevertheless there may be associative

effects when the two chemicals are put together for straw treatment **(**Nguyen *et al*., 2001).

According to Van Soest (1994) calcium hydroxide may enhance the treatment effect of urea because urea normally hydrolyses into ammonium carbonate, a weaker base than ammonia that yields ammonium hydroxide in water as the treatment chemical, when urea is used with lime calcium hydroxide will remove carbonate from ammonium carbonates and generate hydroxide. Calcium hydroxide has been shown to become more effective when combined with ammonia or urea for straw treatment (Males, 1987). High alkalinity induced by lime may inhibit the activity of urease. Research works have indicated, on the one hand, the presence of urease activity and, on the other hand, its partial inhibition under lime plus urea treatment conditions (Pradhan *et al*., 1997). Calcium hydroxide is generally less effective in treating crop residues than other alkaline sources such as NaOH or NH_3 (Meng, 2002). Combining $Ca(OH)_2$ with urea or other alkalis seems to solve this problem. Mao and Feng (1991) showed that rice and wheat straw treatment increased the CP content by 3.5 times (8.3 vs 3.1 %) and *in situ* DM digestibility by 69.8 % (65.9 vs 38.8). In a feeding trial (Feng, 1996), dairy heifers fed such treated rice straw showed significant increases in dietary DM intake (from 6.56 to 6.89 kg), weight gains (from 829 to 898 g/day), feed conversion (7.9:1 to 7.6:1) as compared with those fed the untreated straw. Cao *et al*. (2000) reported significant improvements in the nutritive value of wheat and rice straws as a result of combination treatment with urea, calcium hydroxide and common salt.

Combined treatment reduced the content of NDF, ADF and hemicellulose, but did not change the content of cellulose and lignin over the untreated straw (Cao *et al*., 2000). The *in vitro* DM digestibility of treated straws was enhanced relative to untreated straws (Cao *et al*., 2000). Growth performance data with cross-bred beef cattle fed the combined, ammoniated or untreated rice straw diets revealed that cattle fed the combined diets had somewhat more dietary DM intake, better daily gain, improved feed conversion and considerably reduced feed cost per kg of weight gain than cattle on either untreated or ammoniated straw diet (Cao *et al*., 2000). Saadullah *et al*. (1980) concluded that treatment of rice straw with ammonia through urea is as efficient as anhydrous ammonia. Ngele *et al*. (2009) reported that the crude protein content in crop residues can be increased by ammoniation.

2.12.4 Urea treatment of rice straw

One of the most promising methods of ammoniation is to use fertilizer grade urea as a solution (4–5% w/w) and preserve the sprayed material under air tight conditions for 3–4 weeks (Sundstol andCoxworth, 1984). The method developed by Jackson in India and tested and modified by animal nutritionists in this region (Jayasuriya and Perera 1982) has clearly demonstrated that this treatment increases digestibility and intake of the residue leading to increased animal production. Urea treatment of poor quality roughages has earlier been reported (Lufadeju *et al.,* 1985) to improve feed utilization by enhancing rumen microbial protein synthesis, which increases forage degradation and voluntary intake. Rice straw can also be treated with urea, which releases ammonia after dissolving in water (Schiere and Ibrahim, 1989). For practical use by farmers, urea is safer than using anhydrous or aqueous ammonia and also provide a source of nitrogen (crude

protein) in which straw is deficient (Schiere and Ibrahim, 1989). Urea can be obtained easily in many developing countries as it is easy to handle and transport (Sundstol and Coxwoth, 1984) and cheaper than NaOH or NH_3. The most common NPN source used in ruminant feeding is urea (Whittier, 2013) Many other products have been used experimentally and commercially, but most of them do not compare favourably to urea, because of greater toxicity, higher cost or lower palatability (Whittier, 2013). As treatment of straw with urea can be done under very simple storage conditions (Dolberg *et al*., 1980), and since urea is cheap, easy to handle, the efficiency of urea in straw treatment has made the method potentially available to many more small farmers living in remote villages with poor or no access to roads. Urea, a common chemical fertilizer, is readily available in many parts of the tropics, and is a relatively safe chemical that is easy to store and also easy to dissolve in water. In addition, urea is a solid chemical, so it is easy to handle and transport (Sundstol and Coxworth, 1984). Another advantage of urea is that in many developing countries, it is considerably cheaper than NaOH or ammonia, and is much more readily available (Sundstol and Coxworth (1984). Rice straw and other fibrous materials are normally low in protein (Hang, 2003). Therefore the added nitrogen is considered as one of the advantages of urea treatment **(**Nguyen, 1998). Saadullah *et al*., (1981c) reported an increase of 2.3 –2.5 times the CP in the untreated straw concentration of 33 g/kg DM. Treated straw CP increased significantly with urea concentration in the treatment (Verma *et al*., 1996) and a concentration of 40 to 50 g urea/kg DM straw is considered to be an appropriate level (Verma *et al*., 1996).

The advantage of using higher levels was marginal in terms of digestibility. The magnitude of the CP increase of treated straw varies according to many factors such as material, environment and procedure of the treatment process (Hang, 2003). Variation of material CP concentration determines the magnitude of the increase, and higher increases were noted for straws with low CP concentration after urea treatment, as shown in many studies (Promma *et al*., 1994; Agrawal *et al*., 1989 and Chowdhury and Huque., 1996). In studies on fresh rice straw the CP increases were from 3.6 to 6.4 fold over that of untreated fresh rice straw CP concentration (4.8 % of DM) in the study of Chowdhury and Huque (1996), 2.1 fold in the untreated rice straw (6.88 % of DM) in the study of Man and Wiktorsson (2001). Urea can be a substitute for alkali as a delignification agent through ammoniation. Urea treatment is a conventional technique for improving the quality of rice straw, especially increasing the nitrogen content (Shema *et al.,* 1998). Crude protein intake is a major determinant of ruminant performance due to increase availability of fermentable protein and other nutrient required by rumen bacteria as well as a greater opportunity for dietary protein to escape rumen fermentation (Anele *et al.,* 2010). In sheep rations, the amount of protein is much more important than quality of protein since mature sheep like any other ruminant, use the naturally occurring protein and non-protein nitrogen (urea) in their diets effectively (Clay, 2000).

According to Trach *et al*. (2001) urea treated rice straw could increase overall intake, digestibility thus enhanced the performance of ruminant as compared to untreated rice straw. To increase the nitrogen content, urea treatment of straw promotes saponification of phenolic ester linkages (Dias-da-Silva and Guedes, 1990). According to Hanafi *et al*.

(2012) urea treatment may be the most suitable method for small-scale farmers to improve the quality of straws. It was reported (Khejornsart and Wanapat, 2010) that reducing levels of urea could be used as an alternative to 5% urea for treatment; and that treating rice straw with 3% urea could maintain the nutritive value, especially those of ammonia nitrogen (NH_3-N), total VFA and propionate concentration when compared with 5 % UTRS *in vitro*. An additional effect of urea treatment seems to be that it increases the content of extractable biogenic silica (Shen *et al*., 1998), and thus enhances its digestibility (Dias-da-Silva and Guedes, 1990). Urea, when used for treatment of straw, enhances the nutritional quality of the straw in terms of increased nitrogen content, improved palatability and digestibility (Wongsrikeao and Wanapat, 1985). Urea treatment is also a suitable method for improving the feeding value of rice straw or the nutritional level of a diet based on rice straw (El-shobokshy *et al*, 1989). During the treatment process, ammonia is generated from urea, and in the presence of water it forms an alkali, ammonium hydroxide (Hang, 2003). It has been well-established that alkali treatment makes the cell walls more available for fermentation in the rumen (Hang, 2003). In warmer climates urea treatment is more feasible because of the easy availability of urea and its quick breakdown into ammonia compounds under higher ambient temperatures (Walli *et al.*, 1995). Urea is cheaper, readily available and assumed to be equivalent to anhydrous or aqueous ammonia for upgrading cereal straws in the warmer regions of the world (Jabbar *et al.*, 2009). Urea treatment is also a good preservation method (Wilkins, 1998). Ammonia, trapped in the straw heap or bag, causes an increased straw pH (>8) that inhibits oxidative and microbial fermentation (Wilkins, 1998) and keeps treated straw in a good condition. Urea treatment has emerged as the method of

choice for use at farm level in the tropics as it is best adapted to the condition of smallholder farmers (Chenost, 1995). The use of urea as a precursor of ammonia has been recommended for developing countries with low technological base for its safety in application, availability in the local markets at cheap cost and preservative properties (El-shobokshy *et al*, 1989). However, the adoption rate of this technique remained low (Chenost, 1995). One reason may be the relatively tedious technology and high requirement of labour. O'Donovan *et al.* (1997) reported that the urea treatment process would be popular if it is simple, practical and the material to be used in the treatment is available on the farm. The amount of urea needed to effectively treat straw is considered to be more than the optimum amount of ammonia for microbial growth in the rumen (Chenost, 1995). Urea treatment is a two-stage process consisting of ureolysis, where urea is converted to ammonia and the effect of generated ammonia on the cell walls of the forages being treated (Chenost, 1995).

The key to improve the use of crop residues for ruminants is to overcome the barriers to rumen microbial fermentation of hemicelluloses (Chenost, 1995). The two well-known factors of rice straw that limit bacterial digestion in the rumen are its high level of lignifications and low contents of nitrogen, vitamins and minerals (Chenost, 1995). The author reported that, in principle, there are two approaches, which should be taken in combination, straw delignification treatment and nutrient supplementation (Chenost, 1995). There are many variations in the methods of treatment of low quality roughages with urea. However, the principal method consists of dissolving urea in water and sprinkling it on layers of straw (Chenost, 1995). Water is used to dissolve and hydrolyze

urea in urea treatment and also to act as a means of moving ammonia compounds into the straw (Hang, 2003). Too low water to straw ratios result in low N content, but too wet straw allows fungal growth, particularly if ammonia escapes (Hang, 2003). An amount of water ranging from 30 – 65 liter per 100 kg DM straw seems to be optimum, depending upon the water availability (Rai *et al*., 1993). The level of urea used varies, but it is commonly between 4%-5% of air dried mass of the straw, and the amount of water varies from as low as 0.2 litres per kg of straw (Sundstol and Coxwell, 1984; chenost, 1995). The treatment period depends on the temperature of the surrounding and may be as low as 1 week in warm areas and up to 8 weeks in cold environment (Chenost, 1995).

Increased straw digestibility due to urea treatment has been well documented previously (Doyle *et al*., 1986; Ibrahim and Schiere, 1989). Urea treatment may therefore be most suitable for small-scale farmers to improve the quality of straws particularly varieties showing a low degradability (Sarnklong *et al*., 2010). Urea treatment may also weaken the bonds between the silica-covered cuticles and underlying tissues (Bae *et al*., 1997) thus removing an important barrier to digestion and exposing the underlying silica free tissues to enzymatic action. However, the application of urea treatment by farmers in the village level may be limited due to the fact that it is labour intensive and time consuming and causes management problems (Cheva and Jaerachi, 1987).

2.13 Effect of chemical treatment of rice straw

Chemical treatment of rice straw enhances the nutritional quality of the straw in terms of increased nitrogen content, improved palatability and digestibility (Chenost and Kayouli,

1997). It is also a suitable method for improving the feeding value of rice straw or the nutritional level of a diet based on rice straw (Chenost, 1995). An additional effect of chemical treatment of rice straw seems to be that it increases the content of extractable biogenic silica (Shen *et al*., 1998), and thus enhances its digestibility (Dias-da-Silva and Guedes, 1990). To increase nitrogen content, treatment of rice straw with chemical promotes saponification of phenolic ester linkages (Dias-da-Silva and Guedes, 1990).

2.13.1 Effect of chemical treatment of rice straw on intake and digestibility.

Hart and Wanapat (1992) indicated that chemical treatment like (5 %) urea treated rice straw improved overall intake, nutrient digestibility, VFA production and increased passage rate of particles in the rumen. A comparative study of chemical treatment methods was conducted by Wanapat *et al*. (1985), it was found that based on digestibility and energy utilization studies that the most efficient treatments ranked from highest to lowest were; wet NaOH treatment, dry NaOH treatment, anhydrous NH_3 treatment, urea treatment and untreated rice straw. In addition, the use of ammonia bicarbonate treatment has been shown to increase the fiber digestion kinetics, nutrient digestibility and nitrogen balance (Liu *et al*., 1995). Jayasuriya and Perera (1982) have clearly demonstrated that urea treated rice straw increases digestibility and intake leading to increased animal production. Similarly, Fadel Elseed (2005) and Wanapat *et al*. (2009) reported that urea treated rice straw could increase overall intake, digestibility, thereby enhancing the performance of ruminants.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of the study

The study was conducted at the Livestock Farm of the Department of Agricultural Education, Sa'adatu Rimi College of Education, Kumbotso, Kano State, Nigeria. Kano lies on longitude 9°30' and 12°30' North and latitude 9°30' and 8°42' East on an elevation of 468m. It has a mean daily temperature range of 30°C to 33°C and annual rainfall ranges between 787 and 960 mm (KNARDA, 2001). Kano is characterized by wet and dry climate, a wet season (May-September) and dry season October-April (Olofin, 1987).

3.2 EXPERIMENT 1: Effect of feeding different proportions of urea treated rice straw and gamba hay on performance of growing Yankasa rams

3.2.1 Experimental animals and management

Twenty four (24) growing Yankasa rams aged 6-8 months with mean initial body weight of 15.77±2.5 kg were used for the study. The growing rams were procured from Danbatta and Gezawa markets in Kano State. Prior to the commencement of the experiment, the animals were given prophylactic treatments, consisting of intramuscular injection of Oxytetracycline and Vitamin B complex at the dosage of 1ml/10 kg body weight of the animal. The experimental animals were later drenched with 1ml/10 kg body weight of Albendazole® and treated against ectoparasites with 0.5 ml/10 kg body weight of Ivomec®. The animals were ear-tagged for identification and quarantined for a period of 6 weeks. Adequate feed and clean fresh water were provided to the animals *ad libitum*.

3.2.2 Source of feed and processing

Rice straw (*Oryza sativa* L.) was collected from rice farms in Danhassan, District of Kura Local Government Area of Kano State. The rice straw was chopped manually to a particle length of 3-5cm. Chopped rice straw was treated by dissolving 4.0 kg of urea grade fertilizer in 50 litre of water and sprinkled on 100 kg rice straw (Schiere *et al.*, 1988) and mixed manually. Thereafter, the chopped rice straw materials were stacked for 14 days under air tight condition in PICS (Perdue Improves Cowpea Storage) sacks. The treated rice straw materials were left open to dry for three (3) days and ammonia gas escaped before being fed to the experimental animals.

Gamba hay (*Andropogon gayanus* Kunth) was collected from two villages in Gabasawa Local Government Area of Kano State. The gamba hay was also chopped to a particle size similar to that of the rice straw. The treated rice straw and gamba hay were then bagged and stored in a store for two weeks before being used for animal feeding trial.

3.2.3 Experimental treatments, design and feeding of animals

The dietary treatments consisted of urea treated rice straw (UTRS) and gamba hay (*Andropogon gayanus*) proportions of 0:60, 20:40, 40:20 and 60:0. A concentrate diet consisting of maize grain, cotton seed cake, rice milling waste, wheat bran, bone meal and salt was formulated to contain 15 % crude protein (Table 3.1). The growing rams were balanced for weight and randomly assigned to four dietary treatments with 6 animals per treatment in a Completely Randomized Design. Experimental animals were housed in individual pens of 2m x 1m dimension with corrugated iron roof and a concrete floor. The house was cleaned and disinfected and the animals were individually fed experimental diets. Roughage and concentrate were served in separate feed troughs.

Roughage diet (UTRS:gamba hay) was offered *ad libitum* while concentrate diet was fed at the rate of 1.5 % body weight individually throughout the feeding trial. The feed offered was adjusted at regular intervals of two (2) weeks along with changes in body weight. Clean fresh water was provided to the animals *ad libitum* throughout the period of the experiment. Daily records of feed intakes were taken by weighing the feed offered and the leftover (orts) the following day in the morning. The daily intakes of feed were estimated for each animal by subtracting the feed leftover from the quantity offered to the animals. Weight of individual animals was measured at the onset of the trial after an overnight fasting by withdrawing their feed and water from 7.00 pm to 8.00 am to obtain their initial weights and subsequently at 2 weeks intervals between 8.00 am and 9.00 am throughout the feeding trial. Weight gain was determined by subtracting the initial weights from the final weight within the feeding period.

3.2.4 Blood sampling

Blood samples were collected from the growing rams at the end of the growth trial, at zero time (before morning feeding) and at 2, 4 and 8 hours after feeding. Five (5) ml of blood samples were drawn from the jugular vein of individual animals using sterilized 19-gauge needle and syringe as described by Frandson (1986). The samples were placed in labeled sample bottles without EDTA for biochemical studies according to Ajagbonna *et al*. (1999). The blood samples were thereafter centrifuged for 5-10 minutes at 3000 rpm to separate serum from blood cells (Coles, 1986).

Table 3.1: Composition of concentrate mixtures fed growing Yankasa rams

Ingredients	(%)
Maize	20
Rice mill waste	19
Wheat bran	35
Cotton seed cake	25
Bone meal	0.5
Salt	0.5
Total	100
Calculated CP (%)	15
ME (Kcal/kg)	2753

CP=crude protein, ME= Metabolisable energy

3.2.5 Metabolism trial

At the end of the growth trial, five (5) growing rams were randomly selected from each treatment and housed in metabolic cages for total faecal and urine collection as described by ILCA (1993). The animals were maintained on their respective treatment diets and allowed a 14-day adjustment period to the cages before faecal and urine collection for 7 days. Water was provided *ad libitum*. Feed offered and orts, total faeces and urine voided were recorded for a period of seven (7) consecutive days. At the end of the collection period, all faecal samples from each growing ram were bulked and after thorough mixing, 10 % of it was sub sampled and oven dried at 70 ^{0}C for 48 hours for dry matter determination. Total urine output for 24 hours from each animal was collected into a plastic container containing 20 ml of 0.2N HCl to prevent Nitrogen loss by volatilization (ILCA, 1993). The collected urine was strained through a layer of glass wool to remove detached hair fragments or other solid contaminants. At the end of the 7 day collection period, 10 % of total daily urine collected was sub-sampled and stored in the refrigerator at -16°C until required for Nitrogen determination.

3.2.6 Chemical analysis

Feeds and faecal samples were analyzed for proximate composition by the procedure of A.OA.C. (2007). Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) were analyzed by the Method of Van Soest *et al.* (1991). Nitrogen (N) in the urine samples was determined by Kjeldhal Procedure (AOAC, 2007). The blood samples collected were analyzed for serum urea nitrogen by the Method of Tannins and Maylor (1968). Total protein was estimated by the method of Henry and

Stobel (1957). Serum creatinine was determined according to the method described by Lamb (1991). Serum glucose was determined by the method of Werner *et al*. (1976).

3.3 EXPERIMENT 2: Effect of feeding different proportions of urea treated rice straw and gamba hay on performance of fattening Yankasa rams

3.3.1 Experimental animals and management

Twenty (20) intact Yankasa rams aged 12 – 18 months with mean initial body weight of 21.87±2 kg were used for the study. The rams were procured from Danbatta and Gezawa markets in Kano State. Prior to the commencement of the experiment, the rams were given prophylactic treatments, consisting of intramuscular application of Oxytetracycline and Vitamin B complex at the dosage of 1ml/10 kg body weight of the animal. The animals were drenched with 1ml/10 kg body weight of Albendazole® and treated against ectoparasites with 0.5 ml/10 kg body weight of Ivomec®. The rams were ear-tagged for identification and quarantined for a period of 6 weeks. Adequate feed and clean fresh water were provided to the rams *ad libitum*.

3.3.2 Source of feed and processing

Rice straw (*Oryza sativa* L) was collected from rice farms in Danhassan, District of Kura Local Government Area of Kano State. The rice straw was chopped manually to a particle length of 3-5cm. Chopped rice straw was treated by dissolving 4.0 kg urea in 50 litre of water and sprinkled on 100 kg rice straw (Schiere *et al.*, 1988) and mixed manually. Thereafter, the chopped rice straw materials were stacked for 14 days under air tight condition in PICS (Perdue Improves Cowpea Storage) sacks. The treated rice straw

materials were left open to dry for three (3) days and ammonia gas escaped before being fed to the experimental animals.

Gamba hay (*Andropogon gayanus* Kunth) was collected from two villages in Gabasawa Local Government Area of Kano State. The gamba hay was also chopped to a particle size similar to that of the rice straw. The treated rice straw and gamba hay were then bagged and stored in a store for two weeks before being used for animal feeding trial.

3.3.3 Experimental treatments, design and feeding of animals

The dietary treatments consisted of urea treated rice straw (*Oryza sativa* L) and gamba (*Andropogon gayanus* Kunth) hay proportions of 0:60, 20:40, 40:20 and 60:0. A concentrate diet consisting of maize grain, cotton seed cake, rice milling waste, wheat bran, bone meal and salt was formulated to contain 13 % crude protein (Table 3.2). The rams were weighed and randomly assigned to four dietary treatments with five (5) rams per treatment in a completely randomized design. Experimental animals were housed in individual pens of 2m x 1m dimension with corrugated iron roof and a concrete floor. The house was cleaned and disinfected and the animals were individually fed experimental diets and weighed fortnightly. They were fed concentrate diet at the rate of 2.0 % body weight individually throughout the feeding trial. Roughage diet (UTRS:gamba hay) was offered *ad libitum*. The feed offered was adjusted at regular intervals of two weeks along with changes in body weight. Clean fresh water was provided to the rams *ad libitum* throughout the period of the experiment, which lasted for 90 days. Daily feed intake were recorded for the 90 days of fattening trials by weighing the feed offered and the leftover (orts) the following day in the morning. The daily intake of the diets were estimated for each animal by subtracting the feed leftovers from the

quantity offered to the animals. Weight of individual animals were taken at the onset of the trial after an overnight fasting by withdrawing their feeds and water from 7.00 pm to 8.00 am to obtain their initial weights and subsequently at 2 weeks intervals between 8.00 am and 9.00 am throughout the fattening trial. Weight gain was determined by subtracting the initial weights from the final weights within the fattening period.

3.3.4 Rumen fluid sampling

Rumen fluid samples were collected from animals in the middle of the experiment at 0, 4 and 8 hours after morning feeding. Fifteen (15) ml of the fluid was collected from all the rams in each treatment using stomach suction tube into sterilized bottle. Immediately after collection, the pH of each sample was measured using henna digital hand pH meter (model 9404). Thereafter, 10 ml of the samples were filtered through 4 layers of cheese-cloth to remove particulate matter. The filtered samples were placed in a 30 ml bottle and acidified with 5 drops of concentrated sulphuric acid (H_2SO_4) to trap ammonia and kept in air-tight containers at -20 ^{0}C until required for analysis to determine the concentration of rumen ammonia nitrogen (NH_3-N). *Ammonia nitrogen* concentrations were measured by steam distillation method (Markham, 1942). Total volatile fatty acids (TVFAs) were determined according to the procedure described by AOAC (1990).

3.3.5 Blood sampling

Blood samples were collected from the rams at the end of the fattening trial, at zero time (before morning feeding) and at 2, 4 and 8 hours after feeding. Five (5) ml of blood samples were drawn from the jugular vein of each animal using a sterilized 19-gauge needle and syringe as described by Frandson (1986). The samples were placed in labeled sample bottles without EDTA for biochemical studies according to Ajagbonna *et al*.

(1999).The blood samples were thereafter centrifuged for 5-10 minutes at 3000 rpm to separate serum from blood cells (Coles, 1986).

Table 3.2: Composition of concentrate mixtures fed fattening Yankasa rams

Ingredients	(%)
Maize	25
Rice mill waste	27
Wheat offal	30
Cotton seed cake	17
Bone meal	0.5
Salt	0.5
Total	100
Calculated CP (%)	13
ME (Kcal/kg)	2986

CP= crude protein, ME=Metabolisable energy

3.3.6 Metabolism trial

At the end of the fattening trial, for (4) rams were randomly selected from each treatment and housed in metabolic cages for total faecal and urine collection as described by ILCA (1993). The animals were maintained on their respective treatment diets and allowed a 14-day adjustment period to the cages before faecal and urine collection for 7 days. Water was provided *ad libitum*. Measurements of feed offered and orts, total faeces and urine voided were taken for a period of seven (7) consecutive days. At the end of the collection period, faecal samples from each ram were bulked and after thorough mixing, 10 % of it was sub sampled and oven dried at 70 ^{0}C for 48 hours for dry matter determination. Total urine output for 24 hours from each animal was collected into a plastic container containing 20 ml of 0.2N HCl to prevent Nitrogen loss by volatilization (ILCA, 1993). At the end of the 7 day collection period, 10 % of total daily urine collected was sub-sampled and stored in the refrigerator at -16°C until required for Nitrogen determination.

3.3.7 Cost –benefit analysis

Cost benefit analysis of feeding different proportions of urea treated rice straw and gamba hay to fattening Yankasa rams was assessed using prevailing market prices to cost the concentrate and roughage diets. The cost of the roughage diet was estimated by computing the cost of gamba hay and urea treated rice straw valued at ₦5/kg and ₦15/kg, respectively as at 2015. The cost of the feeds consumed and the value of the weight gain by the rams throughout the fattening trial were computed for each ram.

3.3.8 Chemical analysis

Feeds and faecal samples were analyzed for proximate composition by the Procedure of A.OA.C (2007). Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) were analyzed by the Method of Van Soest *et al.* (1991). Nitrogen (N) in the urine samples was determined by Kjeldhal Procedure (AOAC, 2007). The blood samples collected were analyzed for serum urea nitrogen by the Method of Tannins and Maylor (1968), total protein was estimated by the method of Henry and Stobel (1957). Serum creatinine was determined according to the method described by Lamb (1991). Serum glucose was determined by the method of Werner *et al*. (1976). Rumen ammonia nitrogen (NH_3-N) was measured by micro-kjeldahl technique, using Markham micro-distillation apparatus (Markham, 1942). Total volatile fatty acids (VFAs) was measured using the Procedure described by AOAC (1990).

3.4 Data Analysis

Data collected from the study were subjected to analysis of variance using the General Linear Model Procedure of SAS (2001). Where treatment means were significantly different, Duncan's Multiple Range Test (Duncan, 1955) was used to compare the treatment means. The model used for the experiment is stated below:

$Y_{ij} = \mu + T_i + e_{ij}$

Where

Y_{ijk} = any observation made in the experiment

μ = population means

T_i = Effect due to treatment added or treatment effect

e_{ij} = Experimental error

CHAPTER FOUR

4.0 RESULTS

4.1 Chemical composition of feed ingredients (Experiments 1 and 2)

Table 4.1 presents the chemical composition of untreated rice straw, proportions of urea treated rice straw and gamba hay and concentrate mixtures used in Experiments 1 and 2. The results showed that urea treatment of rice straw increased crude protein content from 3.64 % in untreated rice straw to 8.89 % in rice straw treated with urea. As a result of urea treatment, the NDF content was reduced to 67.98 % from 72.16 %. Similarly, the ADF and ADL contents of untreated rice straw were reduced from 43 % and 11.23 % in untreated rice straw to 41.35 % and 8.57 % respectively in urea treated rice straw. Crude protein content of 2.69 % was obtained for gamba hay (0:60 UTRS:gamba hay). The NDF, ADF and ADL contents of gamba hay recorded were 79.59, 38.56 and 10.78 %, respectively. Crude protein contents of 4.75 and 6.83 % were obtained for 20:40 UTRS:gamba hay and 40:20 UTRS:gamba hay respectively. The NDF, ADF and ADL content obtained for 20:40 UTRS:gamba hay were 75.72, 40.49 and 10.04 %, respectively while the content of NDF, ADF and ADL for 40:20 UTRS:gamba hay were 61.17, 71.85, 40.42 and 9.30 %, respectively. The crude protein, NDF, ADF and ADL contents of concentrate mixtures for Experiments 1 were 14.89, 38.46, 19.88 and 6.29 % respectively while concentrate mixture for Experiment 2 contains crude protein, NDF, ADF and ADL contents of 12.69, 41.32, 20.69 and 6.88 %, respectively.

Table 4.1 Chemical composition of Experimental diets (Experiments 1 and 2)

Parameters	UTRS: GH 0:60	UTRS:GH 60:0	URS 100	UTRS: GH 20:40	UTRS: GH 40:20	CONC 1	CONC 2
DM	90.78	91.11	93.58	90.89	91.00	92.76	88.20
OM	89.20	88.54	90.72	88.98	89.00	85.88	84.65
CP	2.69	8.89	3.64	4.75	6.83	14.89	12.69
NDF	79.59	67.98	72.16	75.72	70.85	38.46	41.32
ADF	38.56	41.35	43.10	40.49	40.42	19.88	20.69
ADL	10.78	8.57	11.23	10.04	9.30	6.29	6.88

UTRS=urea treated rice straw, GH=gamba hay, URS= untreated rice straw, CONC 1=concentrate for experiment 1, CONC 2= concentrate for experiment 2, DM=dry matter, OM=organic matter, CP=crude protein, ADF=acid detergent fibre, ADL=acid detergent lignin

4.2 Experiment 1: Effect of feeding different proportions of urea treated rice straw and gamba hay on performance of growing Yankasa rams

4.2.1 Feed inatake and weight gain of growing Yankasa rams

The results showed significant (P<0.05) differences in dry matter intake between the treatments (Table 4.2). Roughage dry matter intake was significantly higher (P<0.05) in growing rams fed diet containing 60:0 UTRS:gamba hay (325.01 g/day) than in growing rams fed 40:20 UTRS:gamba hay (314.06 g/day) which value was higher (P<0.05) than those fed 20:40 UTRS:gamba hay (277.73 g/day) while those fed 0:60 UTRS:gamba hay had the least (P<0.05) value (263.11 g/day). Concentrate dry matter intake, total dry matter intake and total dry matter intake per metabolic weight followed the same trend. Similarly, significant (P<0.05) differences were observed in the values obtained for crude protein intake and NDF intake. It was observed that the crude protein intake for animals fed diet containing 60:0 UTRS:gamba hay (295.18 g/day) was significantly higher (P<0.05) followed by those on 40:20 UTRS:gamba hay diet (276.41 g/day) whose value was higher (P<0.05) than that of growing rams fed 20:40 UTRS:gamba hay diet (253.03 g/day). Least (P<0.05) value (247.67 g/day) was obtained in growing rams fed 0:60 UTRS:gamba hay diet. There was no significant difference (P>0.05) between the NDF intake for growing rams on 60:0 and 40:20 UTRS:gamba hay diets but differed significantly (P<0.05) compared to those fed 0:60 UTRS:gamba hay diet (406.53 g/day). Lowest (P<0.05) value (401.89 g/day) was obtained for growing rams on 20:40 UTRS:gamba hay diet. Animals on diet containing 60:0 UTRS:gamba hay had the highest (P<0.05) total weight gain (7.18 kg) and daily gain (79.81 g/day) followed by those on 40:20 UTRS:gamba hay and least (P<0.05) value was obtained for animals on

diet containing 0:60 UTRS:gamba hay. Feed conversion ratio (FCR) differed significantly ($P<0.05$) among the treatments. Growing rams fed 60:0 UTRS:gamba hay diet had the least ($P<0.05$) value (7.77) compared to those on 0:60 UTRS:gamba hay diet (11.49). There was significant ($P<0.05$) treatment effect on feed conversion ratio with growing rams fed 60:0 UTRS:gamba hay diet recorded 32.38% improvement in conversion ratio compared to the 0:60 UTRS:gamba hay group. The improvement in feed conversion ratio however decreased with decrease in proportion of urea treated rice straw in the diet when other diets were compared to the 0:60 UTRS:gamba hay diet group.

Table 4.2: Effect of different proportions of urea treated rice straw on feed intake and weight gain of growing Yankasa rams

Parameters	Proportions of UTRS and gamba hay (%)				SEM
	0:60	20:40	40:20	60:0	
DM I (g/day)					
Roughage	263.11^{d}	277.73^{c}	314.06^{b}	325.01^{a}	9.21
Concentrate	247.67^{d}	253.03^{c}	276.41^{b}	295.18^{a}	4.52
Total DMI	510.78^{d}	530.76^{c}	590.47^{b}	620.19^{a}	10.32
Total DMI/kgW$^{0.75}$	64.57^{d}	67.10^{c}	74.65^{b}	78.20^{a}	0.46
CP Intake (g/d)	13.74^{d}	25.21^{c}	40.33^{b}	55.13^{a}	0.53
NDF Intake (g/d)	406.53^{c}	401.89^{d}	418.35^{a}	421.60^{a}	3.54
Initial weight (kg)	15.77	15.77	15.77	15.83	0.31
Final weight (kg	19.76^{d}	20.73^{c}	21.80^{b}	22.95^{a}	0.31
Total wt. gain (kg)	4.00^{d}	4.97^{c}	6.02^{b}	7.18^{a}	0.65
ADG (g/d)	44.44^{d}	55.18^{c}	66.85^{b}	79.81^{a}	6.25
FCR (g/DMI/g gain)	11.49^{a}	9.62^{b}	8.83^{c}	7.77^{d}	0.73

$^{a,b,c,d=}$ Means with different superscripts across the rows differed significantly (P<0.05), UTRS=urea treated rice straw, SEM=standard error of means, ADG= average daily gain, FCR=feed conversion ratio, DMI= Dry Matter Intake

4.2.2 Nutrient digestibility of growing Yankasa rams fed different proportions of urea treated rice straw and gamba hay

The effect of different proportions of urea treated rice straw and gamba hay on nutrient digestibility of growing Yankasa rams is presented in Table 4.3. There were significant differences ($P<0.05$) in digestibility coefficients of DM, OM, CP, NDF and ADF among the treatment groups. Dry matter digestibility was higher ($P<0.05$) in growing rams fed diet containing 60:0 UTRS:gamba hay (67.62%) than in those on 40:20 UTRS:gamba hay diet (65.95%) followed by growing rams on 20:40 UTRS:gamba hay diet (56.72%), while the least ($P<0.05$) value (55.84%) was obtained for growing rams fed diet containing 0:60 UTRS:gamba hay proportion. Organic matter digestibility followed similar trend. Crude protein digestibility in growing rams fed diet containing 60:0 UTRS:gamba hay was significantly higher ($P<0.05$) (67.92%) than in those on 40:20 UTRS:gamba hay (64.55%) whose value differed significantly ($P<0.05$) compared to groups fed diets containing 20:40 and 0:60 UTRS:gamba hay (55.94% and 54.53%, respectively). Digestibility coefficients of NDF, ADF and ADL in growing rams fed diet containing 60:0 UTRS:gamba hay (74.84%, 63.75% and 60.93%, respectively) were higher ($P<0.05$) compared to those fed 40:20 UTRS:gamba hay diet (68.24%, 59.53% and 58.60%, respectively) which had higher ($P<0.05$) values than those on 20:40 UTRS:gamba hay diet (61.69%, 50.52% and 49.64%, respectively), while the least ($P<0.05$) values were obtained for growing rams on 0:60 UTRS:gamba hay diet (56.79%, 47.81% and 45.25%, respectively).

Table 4.3: Effect of different proportions of urea treated rice straw and gamba hay on nutrient digestibility of growing Yankasa rams

Digestibility coeff. (%)	Proportions of UTRS:gamba hay (%)				SEM
	0:60	20:40	40:20	60:0	
Dry matter	55.84[d]	56.72[c]	65.95[b]	67.62[a]	0.62
Organic matter	54.53[d]	55.94[c]	64.55[b]	67.92[a]	0.59
Crude protein	69.23[d]	72.75[c]	75.31[b]	77.94[a]	1.79
Neutral detergent fibre	56.79[d]	61.69[c]	68.24[b]	74.84[a]	1.73
Acid detergent fibre	47.81[d]	50.52[c]	59.53[b]	63.75[a]	0.89
Acid detergent lignin	45.25[d]	49.64[c]	58.60[b]	60.93[a]	0.76

[a,b,c,d:]Means with different superscripts across the row differed significantly ($P<0.05$), UTRS= urea treated rice straw, SEM=standard error of means

4.2.3 Nitrogen balance of growing Yankasa rams fed different proportions of urea treated rice straw and gamba hay

The effect of different proportions of urea treated rice straw and gamba hay on nitrogen balance of growing Yankasa rams is presented in Table 4.4. Nitrogen intake was significantly higher ($P<0.05$) in growing rams fed diet containing 60:0 UTRS:gamba hay (16.12 g/day) than those fed 40:20 UTRS:gamba hay diet (14.66 g/day) which value was significantly higher ($P<0.05$) than the value of those on 20:40 UTRS:gamba hay (13.56 g/day). Growing rams fed 0:60 UTRS:gamba hay diet had the least ($P<0.05$) value (12.06 g/day). There was no significant ($P>0.05$) difference in urinary nitrogen between growing rams fed 60:0, 40:20 and 20:40 UTRS:gamba hay diets. However, the values were significantly higher ($P<0.05$) compared to the value obtained for growing rams on 0:60 UTRS:gamba hay diet. Faecal nitrogen and total nitrogen output values obtained for growing rams fed diet containing 0:60 UTRS:gamba hay (3.43 g/day and 4.28 g/day, respectively) were significantly higher ($P<0.05$) compared to the values for growing rams fed the other treatment diets. Least ($P<0.05$) values (1.82 g/day and 2.82 g/day) were recorded for faecal nitrogen and total nitrogen output respectively in growing rams fed diet containing 60:0 UTRS:gamba hay. Nitrogen absorbed, nitrogen retained and percent nitrogen retention were significantly higher ($P<0.05$) in growing rams fed 60:0 UTRS:gamba hay diet (14.30 g/day, 13.30 g/day and 82.50%, respectively) than in the other treatments while the least ($P<0.05$) values were obtained for growing rams on 0:60 UTRS:gamba hay diet (8.63 g/day, 7.78 g/day and 64.51%, respectively).

Table 4.4: Effect of different proportions of urea treated rice straw and gamba hay on Nitrogen balance of growing Yankasa rams

	Proportion of UTRS:gamba hay				
Nitrogen balance, g/day	0:60	20:40	40:20	60:0	SEM
Total Nitrogen Intake	12.06^{d}	13.56^{c}	14.66^{b}	16.12^{a}	0.66
Urinary Nitrogen	0.85^{b}	0.94^{a}	0.97^{a}	1.00^{a}	0.06
Faecal Nitrogen	3.43^{a}	2.85^{b}	2.12^{c}	1.82^{d}	0.33
Total Nitrogen Output	4.28^{a}	3.79^{b}	3.09^{c}	2.82^{d}	0.21
Nitrogen Absorbed	8.63^{d}	10.70^{c}	12.54^{b}	14.30^{a}	0.52
Nitrogen Retained	7.78^{d}	9.77^{c}	11.57^{b}	13.30^{a}	0.49
Percent N retention	64.51^{d}	72.05^{c}	78.92^{b}	82.50^{a}	3.29

$^{a,b,c,d:}$ Means across the rows with different superscripts differed significantly ($P<0.05$), UTRS=urea treated rice straw, SEM=standard error of mean,

4.2.4 Serum Biochemical profiles of growing Yankasa rams fed different proportions of urea treated rice straw and gamba hay.

Presented in Table 4.5 are the results of serum biochemical profiles of growing Yankasa rams. Serum glucose was significantly higher ($P<0.05$) in growing rams fed diet containing 60:0 UTRS:gamba hay (61.02 mg/dl) compared to the other treatments with the least ($P<0.05$) value (49.55 mg/dl) recorded by growing rams on 0:60 UTRS:gamba hay diet. The trend of glucose over time of sampling (fig. 2) shows that glucose concentration for growing rams on diet containing 60:0 UTRS:gamba hay were numerically higher at 4 hour (61.07 mg/dl) and 8 hour (61.23 mg/dl) post feeding compared to those of growing rams on other diets. Animals fed diets containing 0:60, 20:40 and 40:20 UTRS:gamba hay had higher glucose concentration at 4 hour post feeding after which it declined slightly at 8 hour post feeding. Serum urea concentration differed ($P<0.05$) significantly among the treatments. Growing rams fed diet containing 60:0 UTRS:gamba hay had significantly higher ($P<0.05$) serum urea nitrogen (11.69 mg/dl) than in the other treatments while the least ($P<0.05$) value (6.38 mg/dl) was obtained for growing rams fed diet containing 0:60 UTRS:gamba hay. The trend of urea nitrogen over sampling time (fig. 3) indicated that it increased at 2 hour post feeding up to 4 hour post feeding and declined at 8 hour post feeding. Higher value (12.85 mg/dl) was obtained at 4 hour post feeding for rams fed diet containing 60:0 UTRS:gamba hay. The serum creatinine values for all the treatments were similar ($P>0.05$) across the treatments. The trend of sampling over time for creatinine (fig. 4) showed that the concentration of creatinine increased with UTRS proportion in the diet and also increased linearly with time up to 4 hour post feeding and declined at 8 hour post feeding across the

treatments. Highest value (1.18 mg/dl) was recorded for rams fed diet containing 60:0 UTRS:gamba hay. Growing rams on 60:0 UTRS:gamba hay diet had significantly higher ($P<0.05$) total protein (68.35 g/l) compared to those fed other diets. Lowest ($P<0.05$) value (60.93 g/l) was recorded for growing rams fed diet with 0:60 UTRS:gamba hay. The trend of sampling over time for total protein (fig. 5) had the same pattern with urea nitrogen. The results showed that Total protein reached peak at 4 hour post feeding and declined at 8 hour post feeding. Highest value (69.15 g/l) was obtained for rams fed diet containing 60:0 UTRS:gamba hay.

Table 4.5: Effect of different proportions of urea treated rice straw and gamba hay on serum biochemical profiles of growing Yankasa rams

	Proportions of UTRS:gamba hay (%)				
	0:60	20:40	40:20	60:0	SEM
Glucose (mg/dl)	49.55[d]	53.38[c]	54.67[b]	61.02[a]	0.96
Urea nitrogen (mg/dl)	6.38[d]	7.54[c]	10.06[b]	11.69[a]	0.74
Creatinine (mg/dl)	1.11	1.13	1.14	1.16	0.08
Total protein (g/l)	60.93[d]	62.29[c]	65.86[b]	68.35[a]	0.88

[a, b, c,d]Means across the same row are significantly different (P< 0.05), UTRS= urea treated rice straw, SEM= standard error of means

Figure 2: Effect of time of sampling on serum glucose of growing Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets

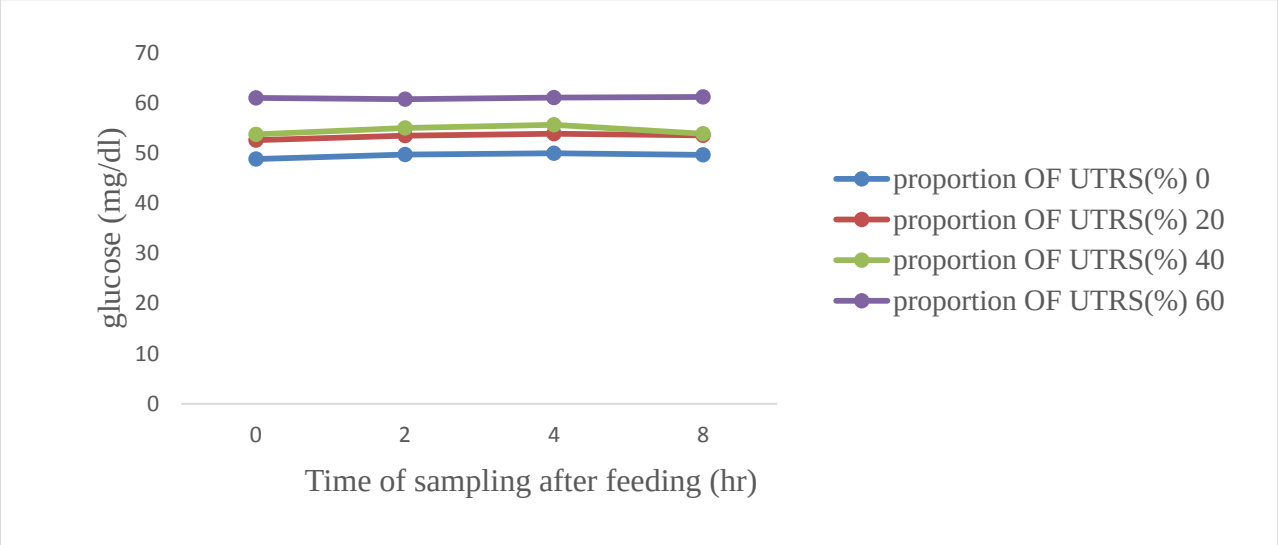


Figure 3: Effect of time of sampling on serum urea nitrogen of growing Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets

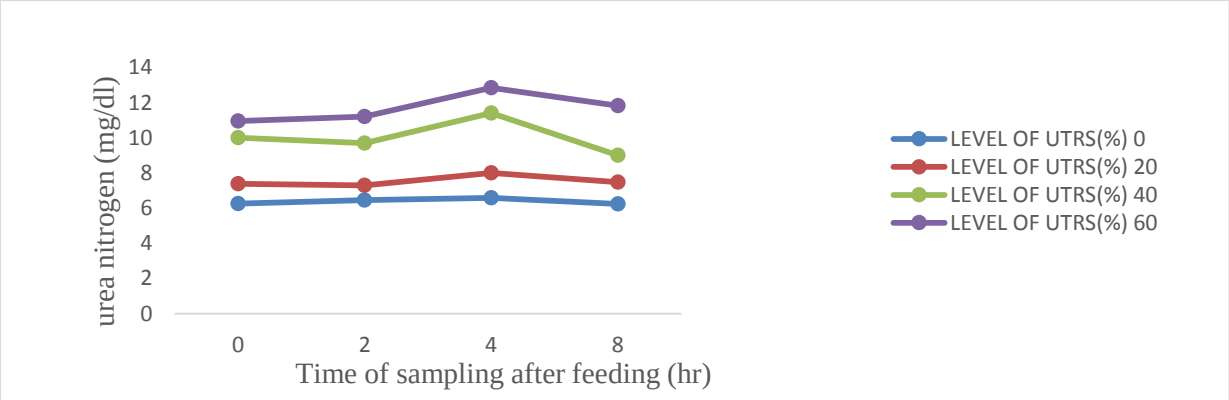


Figure 4: Effect of time of sampling on serum creatinine of growing Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets

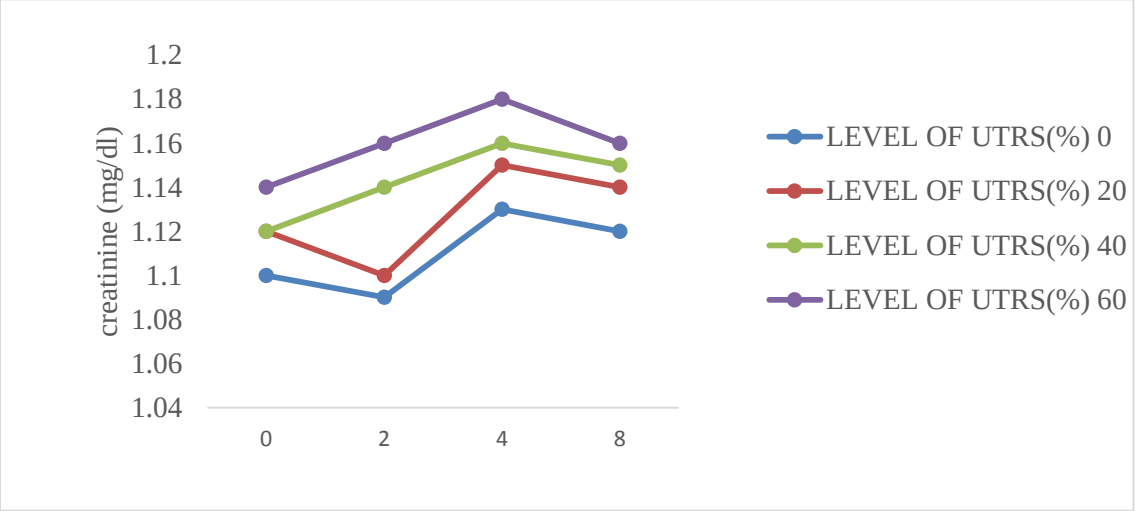
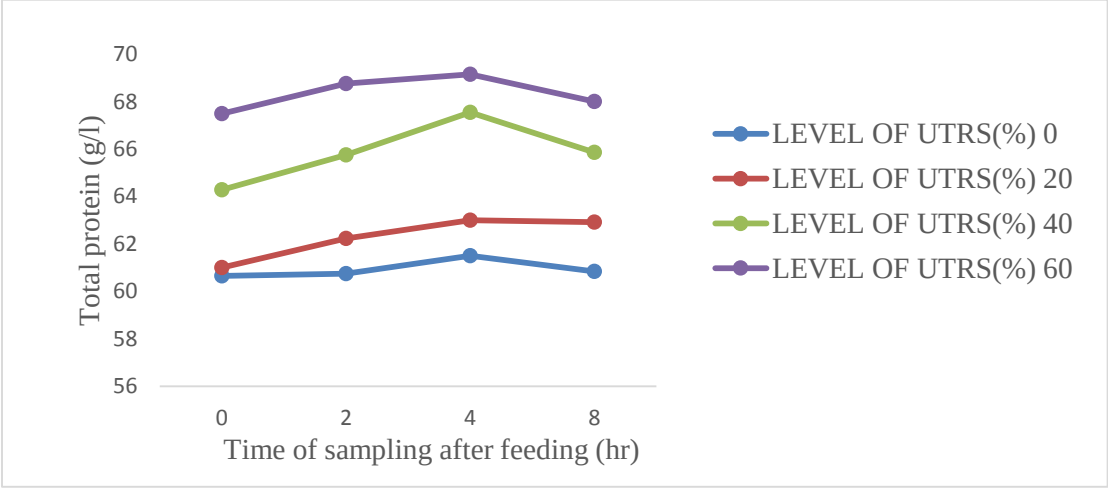


Figure 5: Effect of time of sampling on serum total protein of growing Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets



4.3 EXPERIMENT 2: Effect of feeding different proportions of urea treated rice straw and gamba hay on performance of fattening Yankasa rams

4.3.1 Feed intake and weight gain of fattening Yankasa rams

The results obtained indicated that dry matter intake values differed significantly ($P<0.05$) between the treatments (Table 4.6). Roughage dry matter intake was significantly higher ($P<0.05$) in rams fed diet with 60:0 UTRS:gamba hay (594.61 g/day) than in rams on 40:20 UTRS:gamba hay diet (548.43 g/day) which value was significantly higher ($P<0.05$) than rams fed 20:40 UTRS:gamba hay (466.92 g/day). Least ($P<0.05$) value (445.51 g/day) was recorded in rams fed 0:60 UTRS:gamba hay. There was no significant difference ($P>0.05$) in the value of concentrate dry matter intake.

Total dry matter intake and total dry matter per metabolic weight differed significantly ($P<0.05$) among the treatment groups. Rams fed diet containing 60:0 UTRS:gamba hay had higher ($P<0.05$) values (1035.98 g/day and 102.47/kg$W^{0.75}$, respectively) than those of rams on 40:20 UTRS:gamba hay (987.18 g/day and 97.64/kg$W^{0.75}$, respectively which values were significantly higher ($P<0.05$) than rams fed 20:40 UTRS:gamba hay (895.06 g/day and 89.95/kg$W^{0.75}$, respectively). Lowest ($P<0.05$) values were obtained in rams fed 0:60 UTRS:gamba hay (866.94 g/day and 85.75/kg$W^{0.75}$, respectively). Crude protein intake followed the same trend. Significant differences ($P<0.05$) among the treatments were observed for neutral detergent fibre intake. Neutral detergent fibre intake value for rams fed diet containing 60:0 UTRS:gamba hay was significantly higher ($P<0.05$) (704.26 g/day) compared to that of rams on 40:20 UTRS:gamba hay diet (699.41 g/day) whose value was significantly higher ($P<0.05$) than those fed diet containing 0:60 UTRS:

gamba hay (689.99 g/day). Rams on 20:40 UTRS:gamba hay diet had the least ($P<0.05$) value (677.74 g/day). Total weight gain and average daily gain were significantly higher ($P<0.05$) in rams fed 60:0 UTRS:gamba hay (8.46 kg and 72.89 g/day, respectively) followed by those fed 40:20 and 20:40 UTRS:gamba hay diets with least ($P<0.05$) values (3.42 kg and 38.00 g/day, respectively) in rams fed diet containing 0:60 UTRS:gamba hay. Significant differences ($P<0.05$) among the treatments were observed for feed conversion ratio. Rams fed 60:0 UTRS:gamba hay had the least ($P<0.05$) value (14.21) compared to 22.81, 18.87 and 15.29 for rams on 0:60, 20:40 and 40:20 UTRS:gamba hay diets respectively. Animals fed diet containing 60:0 UTRS:gamba hay were more efficient in converting feed into live weight than animals fed other diets.

Table 4.6: Feed intake and weight gain of fattening Yankasa rams as influenced by different proportions of urea treated rice straw and gamba hay

Parameters	Proportions of UTRS:gamba hay (%)				SEM
	0:60	20:40	40:20	60:0	
DMI (g/day)					
Roughage	445.51[d]	466.92[c]	548.43[b]	594.61[a]	19.00
Concentrate	421.43	428.14	438.75	441.37	25.07
Total DMI	866.94[d]	895.06[c]	987.18[b]	1035.98[a]	27.01
TDMI/kgW$^{0.75}$	85.75[d]	89.95[c]	97.64[b]	102.47[a]	0.44
CP intake (g/d)	23.32[d]	42.51[c]	67.42[b]	92.10[a]	0.58
NDF Intake (g/d)	689.99[c]	677.74[d]	699.41[b]	704.26[a]	3.96
Initial Wt. (kg)	21.86	21.40	21.86	21.88	0.51
Final Wt. (kg)	25.28[d]	25.62[c]	28.68[b]	30.34[a]	0.32
Weight gain (kg)	3.42[d]	4.22[c]	6.82[b]	8.46[a]	0.73
ADG (g)	38.00[d]	47.44[c]	64.55[b]	72.89[a]	5.96
FCR(gDM/g gain)	22.81[a]	18.87[b]	15.29[c]	14.21[d]	0.95

[a,b,c,d:] Means with different superscripts across the row differed significantly (P<0.05), UTRS=urea treated rice straw,TDMI= total dry matter intake, CP=crude protein, NDF=neutral detergent fibre, ADG=Average daily gain, FCR=feed conversion ratio, SEM=standard error of means,

4.3.2 Nutrient digestibility of Yankasa rams fed different proportions of urea treated rice straw and gamba hay

The results of nutrient digestibility of fattening Yankasa rams fed different proportions of UTRS:gamba hay are presented in Table 4.7. There were significant differences ($P<0.05$) in digestibility coefficients of DM, OM, CP, NDF and ADF among the treatment groups. Higher ($P<0.05$) significant value (72.47%) was obtained in dry matter digestibility for rams fed diet containing 60:0 UTRS:gamba hay compared to rams on 40:20 UTRS:gamba hay diet (68.93%) whose value was significantly higher ($P<0.05$) than those on 20:40 UTRS:gamba hay diet (64.30%). Least ($P<0.05$) value (61.60%) was recorded for rams fed 0:60 UTRS:gamba hay diet. Organic matter digestibility was significantly higher ($P<0.05$) in rams fed diets containing 60:0 UTRS:gamba hay (69.51%) followed by rams on 40:20 and 0:60 UTRS:gamba hay diets (67.56% and 67.46%, respectively) whose values were similar ($P>0.05$) while the least ($P<0.05$) value (65.25%) was obtained for rams fed diet containing 20:40 UTRS:gamba hay. Crude protein digestibility was significantly higher ($P<0.05$) in rams fed diet containing 60:0 UTRS:gamba hay (79.26%) than in rams fed 40:20 UTRS:gamba hay diet (76.89%) whose value differed significantly ($P<0.05$) compared to rams on 20:40 and 0:60 UTRS:gamba hay diets (71.11% and 62.53%, respectively). Neutral detergent fibre digestibility followed the same trend. Acid detergent fibre digestibility value for rams fed 60:0 UTRS:gamba hay diet (67.67%) was significantly higher ($P<0.05$) than for those fed diets containing 40:20 UTRS:gamba hay (62.43%) and 20:40 UTRS:gamba hay (61.89%) whose values were similar ($P>0.05$). Rams fed 0:60 UTRS:gamba hay diet had the least

($P<0.05$) value (59.07%). Acid detergent lignin digestibility followed a pattern similar to the acid detergent fbre digestibility.

Table 4.7: Effect of different proportions of urea treated rice straw and gamba hay on nutrient digestibility of fattening Yankasa rams

	Proportions of UTRS:gamba hay (%)				
Digestibility coefficient (%)	0:60	20:40	40:20	60:0	SEM
Dry matter	61.60^{d}	64.30^{c}	68.93^{b}	72.47^{a}	0.83
Organic matter	67.46^{b}	65.13^{c}	67.56^{b}	69.51^{a}	0.76
Crude protein	62.53^{d}	71.11^{c}	76.89^{b}	79.26^{a}	0.90
Neutral detergent fibre	60.64^{d}	65.25^{c}	68.58^{b}	76.93^{a}	0.85
Acid detergent fibre	59.07^{c}	61.89^{b}	62.43^{b}	67.67^{a}	0.45
Acid detergent lignin	49.62^{c}	50.66^{b}	50.97^{b}	51.39^{a}	0.33

a,b,c,d: Means with different superscripts across the row differed significantly ($P<0.05$), UTRS=urea treated rice straw, SEM= standard error of mean

4.3.3 Nitrogen balance of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay

The results of nitrogen balance for fattening Yankasa rams are presented in Table 4.8. Nitrogen intake was higher ($P<0.05$) in rams fed diet containing 60:0 UTRS:gamba hay (19.32 g/day) than in those fed 40:20 UTRS:gamba hay diet (17.71 g/day), which value was significantly higher ($P<0.05$) than in those fed 20:40 UTRS:gamba hay diet (16.53 g/day). Animals on diet containing 0:60 UTRS:gamba hay had the least ($P<0.05$) value (14.13 g/day). There was no significant ($P>0.05$) difference in urinary nitrogen among the treatment groups. Rams on 0:60 UTRS:gamba hay had significantly higher ($P<0.05$) value for faecal nitrogen (3.50 g/day) compared to the values for rams fed the other diets. Rams fed diet with 60:0 UTRS:gamba hay had the least ($P<0.05$) value (1.28 g/day). Total nitrogen output followed the same trend. Nitrogen absorbed, nitrogen retained and percent nitrogen intake values were higher ($P<0.05$) in rams fed diet containing 60:0 UTRS:gamba hay (18.04 g/day, 16.54 g/day and 85.61 %, respectively) than in the other treatments while the lowest ($P<0.05$) values were obtained for rams fed 0:60 UTRS:gamba hay diet (10.63 g/day, 9.40 g/day and 66.52 %, respectively).

Table 4.8: Nitrogen balance of fattening Yankasa rams as influenced by different proportions of urea treated rice straw and gamba hay

	Proportion of UTRS:gamba hay				
Nitrogen balance, g/day	0:60	20:40	40:20	60:0	SEM
Total Nitrogen Intake	14.13[d]	16.53[c]	17.71[b]	19.32[a]	0.51
Urinary Nitrogen	1.23	1.34	1.47	1.51	0.29
Faecal Nitrogen	3.50[a]	2.26[b]	1.64[c]	1.28[d]	0.32
Total Nitrogen Output	4.73[a]	3.60[b]	3.11[c]	2.78[d]	0.30
Nitrogen Absorbed	10.63[d]	14.27[c]	16.07[b]	18.04[a]	0.48
Nitrogen Retained	9.40[d]	11.93[c]	14.60[b]	16.54[a]	0.50
Percent N retention	66.52[d]	72.17[c]	82.44[b]	85.61[a]	3.07

[a,b,c,d:] Means across the rows with different superscripts differed significantly ($P<0.05$), UTRS= urea treated rice straw, SEM=standard error of mean

4.3.4 Rumen fluid metabolites of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay

The results of rumen fluid metabolites are shown in Table 4.9. The mean rumen pH values ranged from 6.66 - 6.97 and were similar (P>0.05) across the treatment groups. The trend of pH over sampling over time (fig. 6) shows that, highest pH value (6.97) was obtained at 4 hour post feeding in rams fed diet containing 0:60 UTRS:gamba hay and lowest (6.05) at 0 hour post feeding in rams fed the same diet. The rumen ammonia nitrogen concentration ranged from 21.79 mg/100 ml for diet containing 0:60 UTRS:gamba hay to 27.80 mg/100 ml for 60:0 UTRS:gamba hay diet which animals had significantly (P<0.05) higher values compared to animals fed the other diets. The trend of ammonia nitrogen over time of sampling (fig. 7) shows that rumen ammonia nitrogen concentrations for rams on diets containing 60:0 and 40:20 UTRS:gamba hay were higher at 0 time, 4hour and 8 hour post feeding compared to the values for rams fed diets containing 0:60 and 20:40 UTRS:gamba hay. Highest value (28.00 mg/100ml) was obtained at 4 hour post feeding for rams fed 60:0 UTRS:gamba hay diet. Ammonia nitrogen concentration after 8 hour started to decline across the treatments. Total volatile fatty acids (TVFA) content followed similar trend with rumen ammonia nitrogen. The trend of sampling over time (fig. 8) shows that the concentration of TVFA increased with increase in UTRS proportion in the diet and also increased linearly with time. Higher values (17.00 and 16.12 Mmol/l) were obtained at 8 and 4 hour post feeding in rams fed diets containing 60:0 and 40:20 UTRS:gamba hay respectively. Lowest value (12.82 Mmol/l) was recorded at 0 hour for rams fed diet containing 0:60 UTRS:gamba hay.

Table 4.9: Effect of different proportions of urea treated rice sraw and gamba hay on rumen metabolites of fattening Yankasa rams

Parameters	Proportions of UTRS:gamba hay (%)				SEM
	0:60	20:40	40:20	60:0	
pH	6.97	6.78	6.66	6.75	0.31
NH_3-N (mg/dl)	21.79^{d}	22.49^{c}	25.26^{b}	27.80^{a}	0.53
TVFA (Mmol/l)	12.98^{d}	13.58^{c}	14.75^{b}	16.13^{a}	0.33

[a,b,c,d:] Means with different superscripts across the row differed significantly ($P<0.05$), NH_3-N=rumen ammonia nitrogen,TVFA=total volatile fatty acids, UTRS=urea treated rice straw SEM=standard error of means

Figure 6: Effect of time of sampling on rumen pH of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets

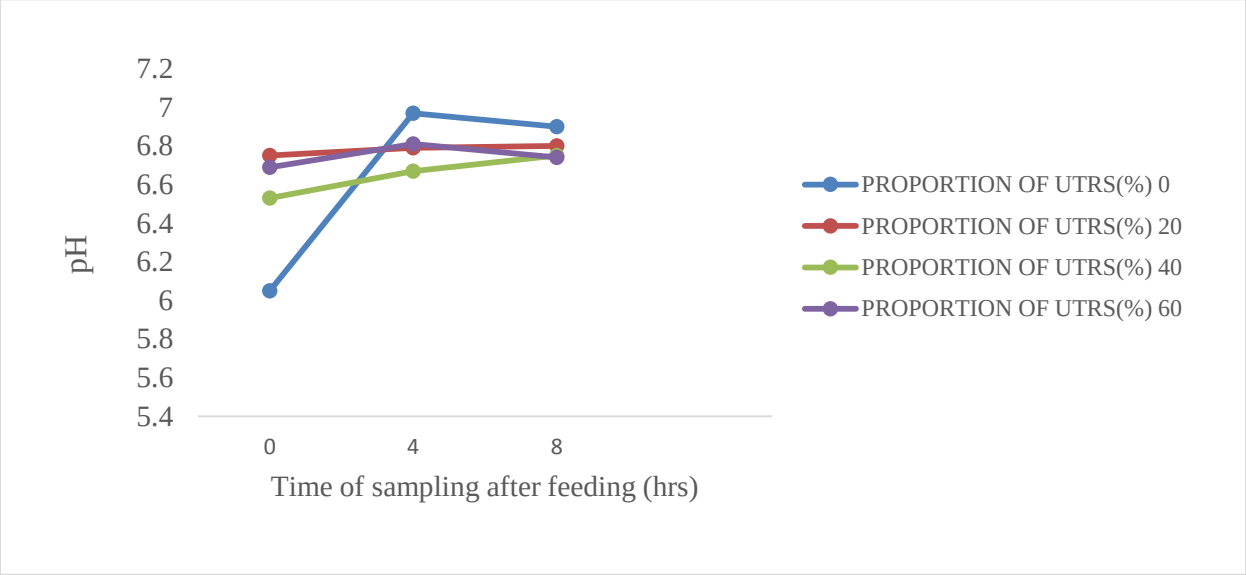


Figure 7: Effect of time of sampling on rumen ammonia nitrogen of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets

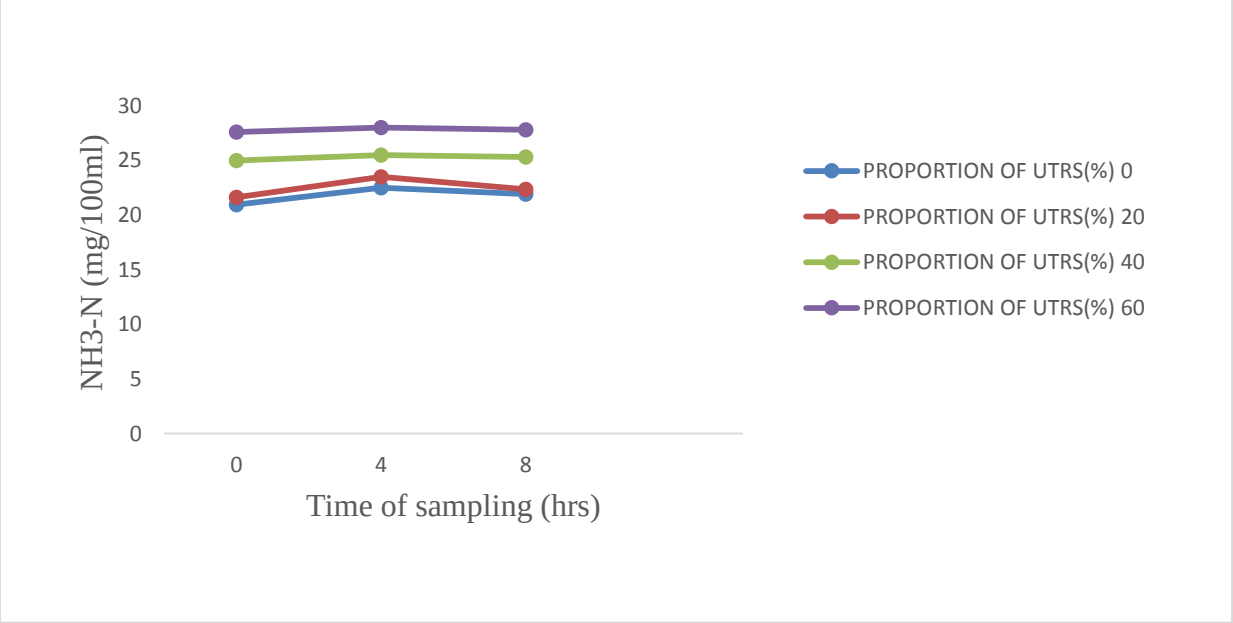
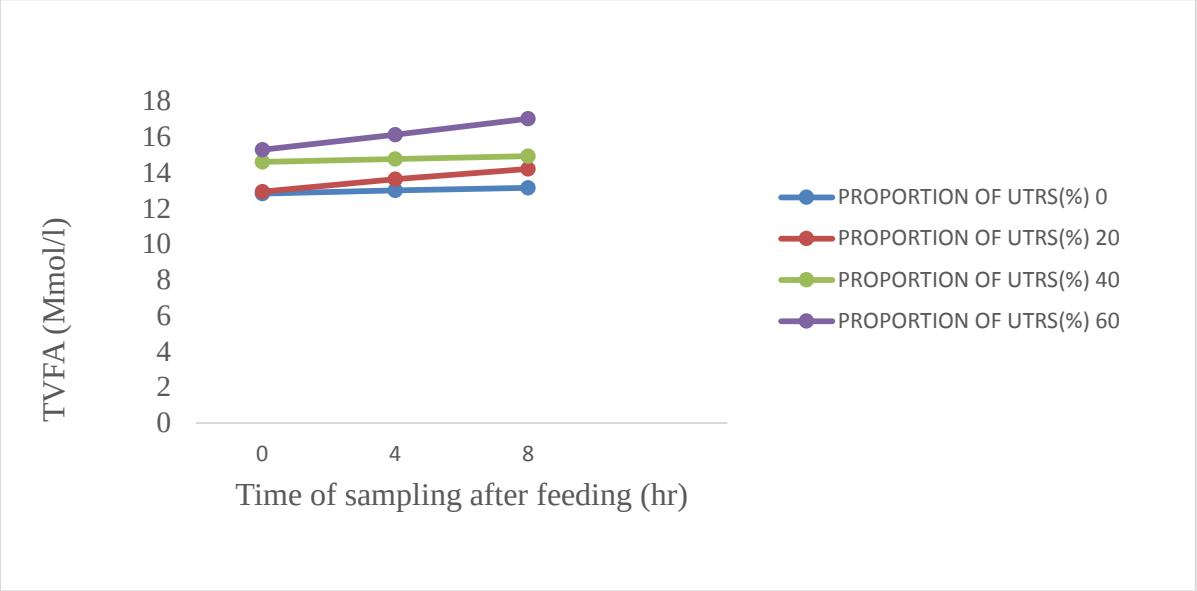


Figure 8: Effect of time of sampling on TVFA of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets



4.3.5 Serum Biochemical profiles of fattening Yankasa rams

The results of serum Biochemical profiles of the fattening Yankasa rams are presented in Table 4.10 There was no significant difference (P>0.05) in serum glucose between rams fed 60:0 and 40:20 UTRS:gamba hay diets (61.37 mg/dl and 60.65 mg/dl, respectively). The values were however, higher (P<0.05) than in rams fed 20:40 UTRS:gamba hay (51.62 mg/dl) which in turn had significantly higher (P<0.05) serum glucose concentration than those fed 0:60 UTRS:gamba hay (50.29 mg/dl). The trend of serum glucose over time of sampling (fig. 9) indicated that it increased at 2 hour post feeding up to 4 hour post feeding across the treatments and declined at 8 hour post feeding. Higher value (62.46 mg/l) was obtained at 4 hour post feeding for rams fed diet containing 60:0 UTRS:gamba hay. Serum urea nitrogen was significantly higher (P<0.05) in rams fed 60:0 UTRS:gamba hay 8.64 mg/dl) compared to those fed 40:20 UTRS:gamba hay (7.40 mg/dl) which value was higher (P<0.05) than in the other treatments. There was no significant difference (P>0.05) between the values recorded for rams fed diet containing 0:60 UTRS:gamba hay (5.98 mg/dl) and rams fed 20:40 UTRS:gamba hay (5.73 mg/dl). The trend of urea nitrogen over time of sampling (fig. 10) indicated that it increased at 2 hour post feeding up to 4 hour post feeding and declined at 8 hour post feeding. Higher value (12.85 mg/dl) was obtained at 4 hour post feeding for rams fed diet containing 60:0 UTRS:gamba hay. Serum creatinine concentration was similar (P>0.05) among the treatment groups. The trend of sampling over time for creatinine (fig. 11) showed that the concentration of creatinine in rams fed 0:60 and 20:40 UTRS:gamba hay diets increased linearly with time up to 4 hour post feeding and declined at 8 hour post feeding. Animals fed 20:40 UTRS:gamba hay diet had higher value (1.18 mg/dl) at 4 hour post feeding.

Animals on 40:20 and 60:0 UTRS:gamba hay diets had increase in serum creatinine linearly with time. Higher values (1.17 and 1.15 mg/dl) were obtained in animals fed diets containing 40:20 and 60:0 UTRS:gamba hay respectively at 8 hour post feeding. The total protein values for rams fed 60:0 and 40:20 UTRS:gamba hay were similar ($P>0.05$) (67.03 g/l and 66.51 g/l, respectively), but significantly higher ($P<0.05$) than for rams fed 20:40 UTRS:gamba hay (62.52 g/l). Fattening rams on 0:60 UTRS:gamba hay diet had the lowest ($P<0.05$) total protein concentration (58.77 g/l). The trend of sampling over time for total protein (fig. 12) had the same pattern with urea nitrogen in which the TP reached peak at 4 hour post feeding and declined at 8 hour post feeding. Highest value (69.15 g/l) was obtained for rams fed diet with 60:0 UTRS:gamba hay.

Table 4.10: Effect of different proportions of urea treated rice straw and gamba hay diets on serum biochemical profiles of fattening Yankasa rams

Parameter	Proportions of UTRS:gamba hay (%)				SEM
	0:60	20:40	40:20	60:0	
Glucose (mg/dl)	50.29[c]	51.62[b]	60.65[a]	61.37[a]	0.81
Urea nitrogen (mg/dl)	5.73[c]	5.98[c]	7.40[b]	8.64[a]	0.62
Creatinine (mg/dl)	1.12	1.18	1.14	1.12	0.07
Total protein (g/l)	58.77[c]	62.52[b]	66.51[a]	67.03[a]	0.92

[a, b, c]Means are significantly different (P< 0.05) across the same row, UTRS=urea treated rice straw, SEM= standard error of means

Figure 9: Effect of time of sampling on serum glucose of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets

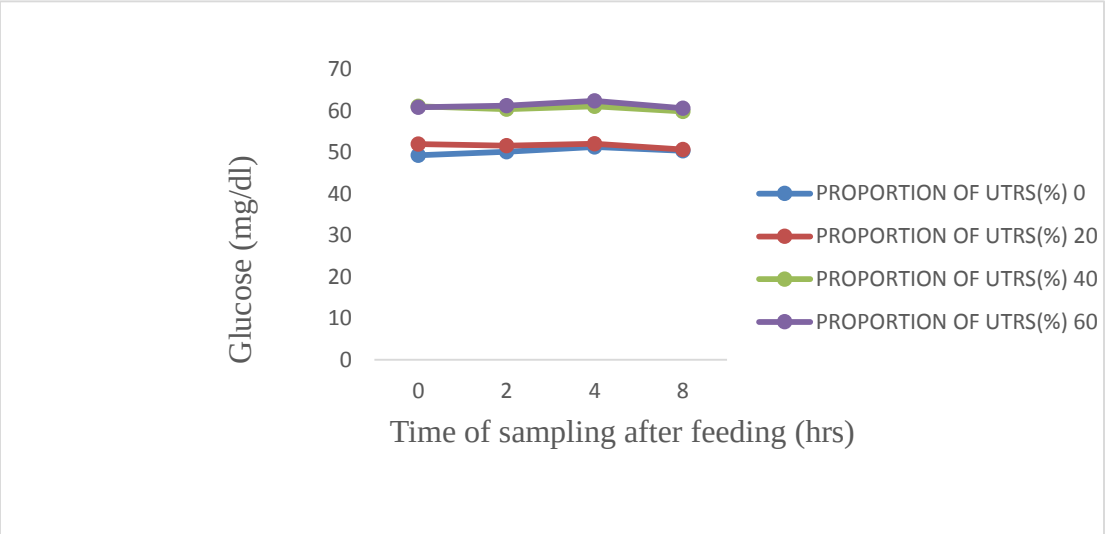


Figure 10: Effect of time of sampling on serum urea nitrogen of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets

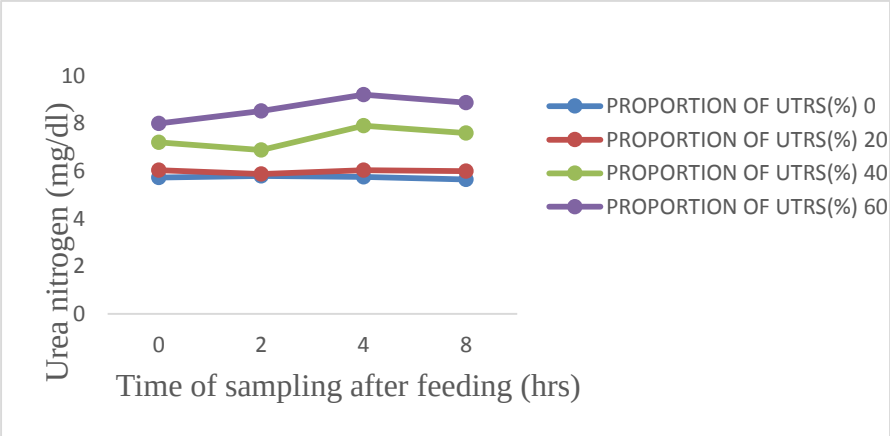


Figure 11: Effect of time of sampling on serum creatinine of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets

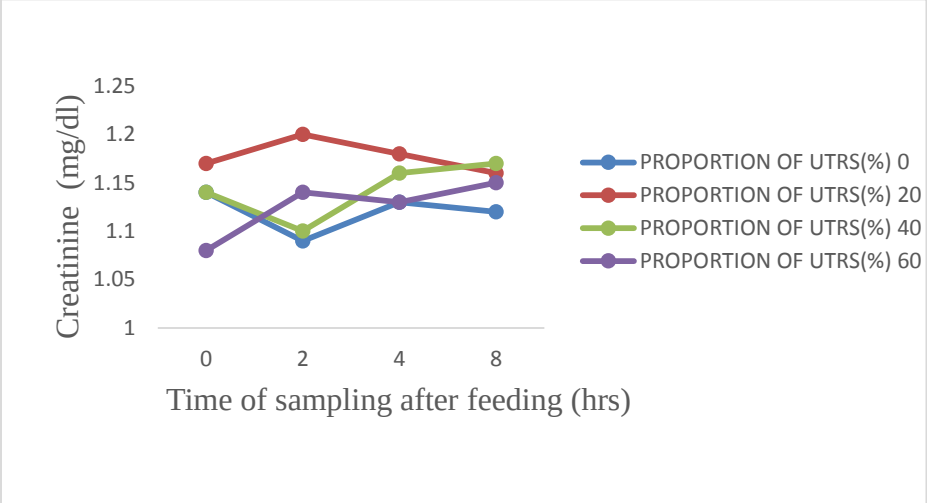
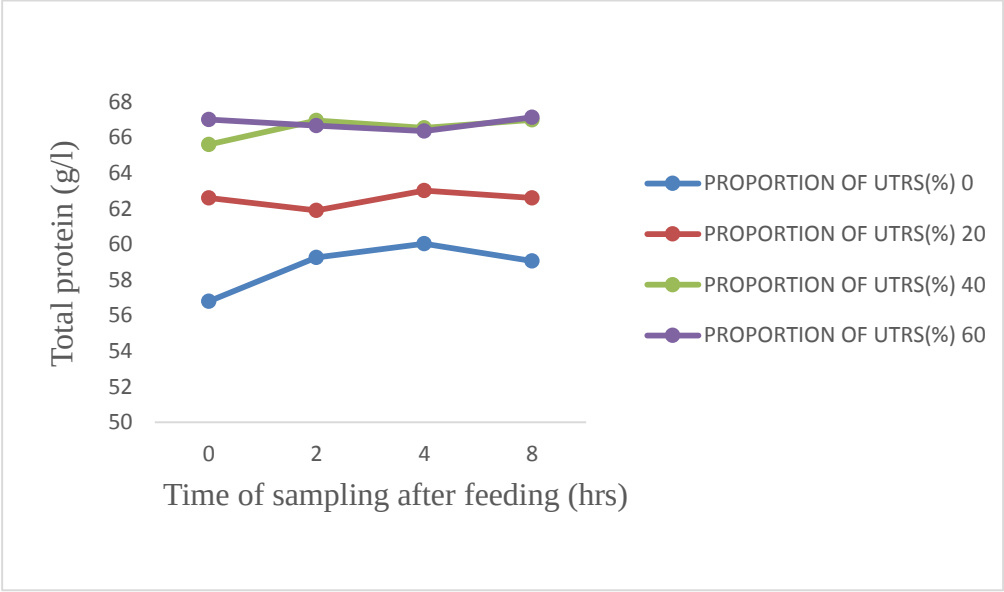


Figure 12: Effect of time of sampling on serum total protein of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay diets



4.3.6 Cost benefit analysis

The cost-benefit analysis of feeding different proportions of urea treated rice straw and gamba hay to fattening Yankasa rams is shown in Table 4.11. The rams on 0:60, 20:40, 40:20 and 60:0 UTRS:gamba hay diets had total weight gain of 3.42 kg, 4.22 kg, 6.82 kg and 8.46 kg, respectively. The cost of concentrate consumed increased from ₦2021.42 in the diet with 0:60 UTRS:gamba hay to ₦2047.89 in the diet with 60:0 UTRS:gamba hay. Similarly, cost of roughage consumed and total feed consumed increased from ₦345.05 and ₦2366.47 in the diet with 0:60 UTRS:gamba hay to ₦454.97 and ₦2502.86 in the diet with 60:0 UTRS:gamba hay respectively. However, the cost of total feed consumed per kg live weight gain was lowest ($P<0.05$) for rams fed 60:0 UTRS:gamba hay diet (₦ 497.76) compared to their counterparts fed other diets with values increasing with decreasing dietary levels of urea treated rice straw.

Table 4.11 Cost-benefit analysis of feeding different proportions of urea treated rice straw and gamba hay to fattening Yankasa rams

Parameter	Proportion of UTRS:gamba hay (%)				SEM
	0:60	20:40	40:20	60:0	
Total weight gain (kg)	3.42[c]	4.22[c]	6.82[b]	8.46[a]	0.93
Concentrate intake (g/d)	421.43[d]	428.14[c]	438.43[b]	441.37[a]	25.07
Roughage intake (g/d)	445.51[d]	466.92[c]	548.75[b]	594.61[a]	19.00
Total DM intake (g/d)	866.94[d]	895.06[c]	987.18[b]	1035.98[a]	27.01
CCC (₦)	2021.42[d]	2025.14[c]	2038.39[b]	2047.89[a]	2.63
CRC (₦)	345.05[d]	353.43[c]	382.87[b]	454.97[a]	7.21
CTFC(₦)	2366.47[a]	2378.57[b]	2421.26[c]	2502.86[c]	10.50
CTFC/kg/gain (₦/kg)	691.95[a]	563.64[b]	523.31[b]	497.76[c]	5.21

[a,b,c,d:] Means across the same rows with different superscripts differed significantly ($P<0.05$), UTRS=urea treated rice straw, SEM= standard error of means, CCC= Cost of concentrate consumed; CRC= Cost of roughage consumed CTFC= cost of total feed consumed

CHAPTER FIVE

5.9 DISCUSSIONS

5.1 Chemical composition of experimental feeds (Experiments 1 and 2

The chemical composition of untreated rice straw, proportions of urea treated rice straw and gamba hay and concentrate mixtures for experiments 1 and 2 (Table 4.1) indicated that urea treatment increased the crude protein content of the rice straw from 3.64 % in the untreated rice straw to 8.89 % after treatment with urea. This result is in agreement with the findings of Puri and Gupta (2001) who reported that crude protein content of rice straw increased from 3.40 % in untreated to 8.04% in urea treated straw. Several authors have also reported increases in crude protein content of cereal straws as a result of urea treatment (Jackson, 1977; Saadullah *et al*., 1981; Promma *et al*., 1994 and Chetna Bhatt *et al*., 2004). The increase in crude protein content of treated rice straw is associated with the conversion of urea into ammonia during treatment period, part of which may have been organically bound with treated straw (Chetna Bhatt *et al*., 2004). The reduction in NDF content of urea treated rice straw from 72.16 to 67.98 % observed in this study was comparable to earlier reports (Singh *et al*., 2001; Chetna Bhatt *et al*, 2004 and Midau *et al*., 2015). The decrease in NDF content was due to solubilization of hemicelluloses content during treatment of straw and its subsequent removal from cell wall constituents (Givens *et al.*, 1988 and Chetna Bhatt *et al*., 2004). The observed decrease in ADL content by urea treatment could be ascribed to the breakdown of lignocellulose bond through ammonium hydroxide (NH_4OH) formation in the stack during treatment as ascertained by Punj *et al*. (1977). Rehrahie (2001) reported that most data reviewed have shown decreased fibre fractions and a considerable increase in crude protein contents of

crop residues due to urea treatment. The crude protein content of 2.69% obtained for gamba hay in this study was lower than the 3.50 % CP of gamba hay reported by Alli-Balogun (2010). The NDF content of gamba hay (70.59 %) was also lower than the 75.95 % obtained by Alli-Balogun (2010) and 76.4% obtained by Lufadeju (1988). Similarly, the value of ADF obtained in this study was lower than 56.2 % reported by Lufadeju (1988). The differences in values may be attributed to variation in soil fertility, maturity or time of harvest, leaf to stem ratio, cultivar, curing and method of processing which affect the chemical composition (Fuglie, 1991; Lambert and Litherland, 2000; Ajiji *et al*., 2013).

5.2 Experiment 1

5.2.1 Feed intake and weight gain

The significantly higher total dry matter intake observed in growing rams fed diets containing urea treated rice straw hay could be due to increased availability of nutrients as a result of urea treatment. Urea treatment of poor quality roughages has been reported to improve feed utilization by enhancing rumen microbial synthesis thereby increasing forage degradation and voluntary intake (Lufadeju *et al*., 1985). The CP and NDF intakes observed in growing rams fed diets containing urea treated rice straw might be attributed to the higher CP and NDF digestibility (Table 4.3). The higher CP intake values obtained in growing rams fed urea treated rice straw diet was in conformity with Narayan *et al*. (2004) who found a higher CP intake when urea treated wheat straw was fed to goats and lactating buffaloes.The significantly higher total weight gains and daily weight gains in growing rams fed diets containing 60:0 and 40:20 UTRS:gamba hay compared to those

fed 20:40 and 0:60 UTRS:gamba hay diets might be due to increasd dry matter intake and nutrient utilization. Puri and Gupta (2001) and Saadullah *et al.* (1982) reported that improvement in gain was directly related to the dry matter intake. The results wre in agreement with what was reported by Finangwai and Dafur (2015) that treatment of acha straw with urea had a positive effect on weight gain. Ibrahim *et al*. (1989) however found no effect of urea treatment on animal performance. The increased total weight gain and average daily gain could be due to increased nitrogen availability in the digestive tract for effective degradation of straw. The least feed conversion ratio (FCR) value (7.77) obtained indicated that growing rams on diet containing 60:0 UTRS:gamba hay were more efficient in converting feed to live weight gain than the growing rams fed other diets.

5.2.2 Nutrient digestibility

Increased apparent digestibility of DM, OM and CP in growing rams fed diets containing urea treated rice straw was in agreement with the results of Wanapat *et al*. (2009) who reported that urea treatment of rice straw improved digestibility of DM, OM, and CP in dairy cows when fed urea treated rice straw based diet. Prasad *et al*. (1998) also reported increase in CP digestibility in crossbred cows fed baled and stacked urea treated rice straw. The higher apparent digestibility of NDF and ADF recorded in diets containing urea treated rice straw was in line with the report of Hart and Wanapat (1992) who found that treatment of rice straw with urea increased digestibility of NDF and ADF contents. The results also agreed with the finding of Abdu (1998) who reported increased digestibility of urea treated sorghum stover. It was also reported by Djas-da-Silva and Guedes (1990) that an additional effect of urea treatment seems to be that it increases the

content of extractable biogenic silica, and thus enhances its digestibility. Increase in digestibility of NDF and ADF contents of urea treated rice straw could be attributed to the swelling of the hemicelluloses-lignin complex (Mapato *et al*., 2010) resulting in an increased surface area available for attack by rumen microorganisms and thus increasing the rate of breakdown and the rate of passage of treated straw through the digestive tract. (Goto and Yokoe, 1996; Ha *et al.,* 2001). Dahiya *et al*. (1990) and Rai and Agrawal (1991) reported that the significant improvement in the digestibility of fibre fractions of urea treated rice straw could be attributed to either incorporation of N in the nitrogen deficient rice straw or alteration of lignocellulose complex or both.

5.2.3 Nitrogen balance

The higher nitrogen intake in growing rams fed diet containing urea treated rice straw could be attributed to higher crude protein in the diets following urea treatment. This was in line with Preston and Leng (1987) who reported that crude protein concentration in a diet has a significant effect on the nitrogen intake of sheep. Increased nitrogen absorbed and nitrogen retained in groups fed diets with urea treated rice straw may be as a result of the higher crude protein content of the straw due to urea treatment. The significant differences in nitrogen retention from urea treated rice straw diets indicated that the nitrogen in treated rice straw was adequate for the amount of energy available from its fermentation. Animals fed diet containing (0:60 UTRS:gamba hay) in this study had lower nitrogen retention, as did the sheep of Adu and Adamu (1982) which were fed three low crude protein tropical grass hays. The result also conformed to the report by Abubakar *et al*. (2010) who evaluated different sources of nitrogen and recorded positive nitrogen balance for those fed urea sources. The increased nitrogen retention in this study

agreed with Pradhan *et al.* (1995) who reported that urea treated rice straw increased nitrogen retention in goats.

5.2.4 Serum profiles

The results showed significant differences ($P<0.05$) in serum glucose, urea nitrogen and total protein, while there was no significant difference in creatinine across the treatment groups. Finangwai *et al*. (2010) reported non-significant differences in serum glucose, urea nitrogen and creatinine in crossbred (Friesian× Bunaji) bulls fed urea treated maize stover based complete diets. The glucose concentration values were within the normal range of 40-100 mg/dl (Merck, 2016). The total serum protein values recorded in all the treatment groups fell within normal physiological ranges of 60 - 82g/l (Singh and Gupta, 1986; Farghly *et al*., 1993).

5.3 Experiment 2

5.3.1 Feed intake and weight gain

The significantly higher ($P<0.05$) total dry matter intake in fattening rams fed diets containing urea treated rice straw may be a reflection of increased palatability and digestibility of the straw. Mc Donald *et al*. (1995) observed that there is a positive relationship between digestibility and feed intake. Chenost and Kayouli (1997) also attributed feed intake to improved palatability and softening effect of urea treatment on rice straw. The authors further reported that urea treatment increase intake of rice straw in the range of 15 to 50 %.The present result was also in agreement with the report of Finangwai *et al*. (2008) that urea treatment of straw increased feed intake in crossbred bulls. The increase in CP, and NDF intake observed in this study could be due to better

digestibility of the nutrients (Table 4.3.). Higher total weight gain and average daily gain in groups fed roughage containing urea treated rice straw could be a result of increased dry matter intake. The result was in line with the findings of Saadullah *et al*. (I982), Puri and Gupta (2001) and Finangwai and Dafur (2015).

5.3.2 Nutrient digestibility

Increased digestibility coefficient values for DM, OM and CP in rams fed diets containing urea treated rice straw obtained in this study agree with Doyle *et al*. (1987; Hart and Wanapat (1992) and Trach *et al*. (2001) who reported increase in nutrient digestibility in ruminants fed straw treated with urea. The higher apparent digestibility of NDF and ADF recorded in diets containing urea treated rice straw was in line with the report of Ibrahim and Schiere (1989) and Hart and Wanapat (1992) who found that treatment of rice straw with urea increased digestibility of NDF and ADF contents. Prasad *et al*. (1998) reported higher nutrient digestibility of OM, CP and of the fiber fractions for urea treated straw diets than for untreated straw fed to crossbred cows. Moreover, Dutta *et al.* (2004) and Gunun and Wanapat 2012 reported increased digestibility of NDF and ADF in goats and dairy steers fed urea-treated rice straw. Increase in digestibility of NDF and ADF contents of urea treated rice straw could be attributed to the swelling of the hemicelluloses-lignin complex (Nurfeta *et al*., 2009; Mapato *et al*., 2010) resulting in an increased surface area available for attack by rumen microorganisms and thus increasing the rate of breakdown and the rate of passage of treated straw through the digestive tract (Goto and Yokoe, 1996; Ha *et al*., 2001).

5.3.3 Nitrogen balance of fattening Yankasa rams fed different proportions of urea treated rice straw and gamba hay

The higher total nitrogen intake, nitrogen absorbed and nitrogen retained observed for rams fed diets containing urea treated rice straw might be attributed to higher crude protein in the diets. This was in line with the reports by Preston and Leng (1987) and Abubakar *et al*. (2010). The higher significant value obtained for urinary nitrogen output on animals fed diets containing urea treated rice straw when compared to group fed 0:60 UTRS:gamba diet could be a reflection of higher nitrogen intake. This was in conformity with the findings of Kerchgessner *et al.* (2001), who reported that nitrogen consumed in excess of animal requirement will be excreted in urine. The higher values of faecal nitrogen observed on animals fed diet containing 0:60 UTRS:gamb hay could probably be due to reduced digestibility of crude protein that was not well utilized and thus was excreted. In contrast with these results, Sinha *et al*. (2011) did not find any significant effect on total nitrogen intake, faecal and urinary nitrogen excretion in Mithun (*Bos frontalis*) fed urea-treated paddy straw when compared to Napier grass (*Pennisetum purpureum* Schumach).

5.3.4 Rumen metabolites

The rumen pH values of the treatment groups obtained in this study agree with the recommended standard rumen pH values of 6.7 reported by Van Soest (1994). Van Soest (1994) reported that cellulolytic organisms grow optimally at pH 6.7 and pH below 6.2 inhibited the rate of digestion, decreased acetic acid and depressed cellulolytic activity. In this study, treatment of rice straw with urea had no effect on rumen pH, an indication of balance between the concentrations of VFA and NH_3 in

the rumen as described by Alam, *et al.* (2010). The results showed significantly higher rumen ammonia concentration in animals fed diets containing 60:0 and 40:20 UTRS:gamba hay compared to those fed 20:40 and 0:60 UTRS:gamba hay diets. The significant difference observed in the values obtained for ammonia nitrogen concentration in the rumen fluid of rams fed diets containing 60:0 and 40:20 UTRS:gamba hay could be due to the extent of CP digestibility and nitrogen uptake by the rumen microbes. Evidence from literature indicate that the minimum rumen ammonia concentration required vary depending on the type of fibrous material being digested (Dixon, 1987). The result was consistent with previous studies which indicated that urea treatment of straw increased rumen ammonia concentration (Farghly, 1993; Wanapat *et al*., 2009 and Mapato *et al*., 2010). The values (21.79 – 27.80 mg/dl) for rumen NH_3-N concentrations obtained in this study were similar to the NH_3-N range of 15 to 30 mg/dl reported by Wanapat *et al.,* 2008; Poungchompu *et al*., 2009; Anantasook *et al*., 2013). The higher TVFA concentration observed in the groups fed diets containing 60:0 UTRS:gamba hay might be a result of increased feed intake and digestibility as reported by Jayasuriyya *et al*. (1987) and Nisa *et al*. (2014). Those groups with higher nutrient digestibility showed higher values of TVFA (Table 4.3.2). The increase in TVFA could be due to higher crude protein in the diets which provided adequate nitrogen required for rumen microbes to maximally digest the components of dietary fibre, leading to the production of total volatile fatty acid as reported by Givens and Moss (1993). Ipharrauerre *et al*. (2005) also reported that the concentration of TVFA in the rumen fluid of cattle increased with increased crude protein content of the diet.

5.3.5 Serum metabolites

The significant differences in serum glucose, urea nitrogen and total protein and the non significant effect in serum creatinine obtained in this study did not conform to the values reported by Finangwai *et al*. (2010) when they fed urea treated maize stover based complete diets to crossbred (Friesian × Bunaji) bulls. The increased serum glucose in rams fed diets containing urea treated rice straw could be a result of increased intake of soluble carbohydrate leading to increase in the level of blood glucose. This is in support of Abd El Latif (2003) who indicated that values of blood glucose concentration in growing Friesian calves were correlated with energy in the diets. The higher values of blood urea nitrogen concentration for rams fed diets containing urea treated rice straw proportion might be a result of high release of ammonia in rumen resulting in high absorption of ammonia from the rumen to the blood (Sano *et al*., 2009; Abubakar *et al*. 2010). Gunun *et al*. (2013) also reported increased blood urea nitrogen concentrations with increasing rumen ammonia nitrogen level when cows were fed urea treated rice straw. Similarly, Yadav and Yadav (1988) found that, cattle given ration containing urea treated straw showed higher serum urea concentration than those fed untreated paddy straw. Values obtained for the serum parameters in this study fell within the normal range of serum glucose, urea nitrogen, serum creatinine and total protein fell within the normal ranges of 50-100 mg/dl, 15-30 mg/dl, 1-2.7 mg/dl and 60-79 g/l, respectively for sheep (Kaneko, 1989; Banerjee, 2007; Merck, 2016). The higher values of total serum protein obtained for rams fed diets containing urea treated rice straw could probably be due to increased crude protein content of the diet as well as higher crude protein intake.

5.3.6 Cost- benefit analysis

The higher cost of total feed consumed recorded in rams fed diets containing urea treated rice straw could be due to the higher dry matter intake compared to animals fed diet containing 0:60 UTRS:gamba hay. The cost of feed consumed per kg live weight gain was lower and better in rams fed 60:0 and 40:20 UTRS:gamba hay diets compared to the other treatment groups. This result agreed with Singh *et al.* (2001) who reported that treatment of rice straw with urea significantly increased live weight gain and average daily gain which in turn lead to reduced cost of feed per kg live weight gain of crossbred heifer.

CHAPTER SIX

6. 0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. Crude protein content increased from 3.64 in untreated rice straw to 8.89 % in urea treated rice straw while the NDF decreased from 72.16 to 67.98 % as a result of urea treatment.

2. Dry matter intake in growing and fattening rams fed diets containing 60:0 and 40:20 urea treated rice straw:gamba hay was significantly higher than those on 20:40 and 0:60 urea treated rice straw:gamba hay diets.

3. Daily weight gain was significantly higher in growing and fattening rams fed 60:0 and 40:20 urea treated rice straw:gamba hay diets compared to those fed 20:40 and 0:60 urea treated rice straw:gamba hay diets.

4. Digestibility coefficients of DM, OM, CP, NDF and ADF were significantly increased in diets containing urea treated rice straw.

5. Blood serum and rumen fluid metabolites were within the normal physiological ranges for sheep.

6. Cost of feed consumed per kg body weight gain was lower and better in fattening rams fed diets with 60:0 and 40:20 urea treated rice straw:gamba hay proportion.

6.2 Recommendations

The study recommends as follows:

1. Urea treated rice straw could be used to replace gamba hay as a roughage source for sheep feeding as sheep had higher weight gain in the urea treated rice straw based diets compared to gamba hay based diet.

2. Small-holder farmers may adopt the treatment of rice straw with urea to improve its nutritive value and reduce the cost of feed per kg body weight gain.

REFERENCES

Abbey, T.K., Alhassan, A., Ameyibor, K., Essiah, J.W., Fometu, E. and Wiredu, M.B. (2001). Cattle, sheep and goat production. In: Integrated Science for Senior Secondary Schools. Unimax Macmillan Ltd., 42 Ring Road South, Industrial Area, Accra North, Ghana. pp. 356.

Abd El-Latif, E.S.K. (2003). Nutritional studies on beef cattle. M Sc. Thesis, Faculty of Agriculture, Cairo University, Cairo Pp 119

Abdu, S.B. (1998). Effect of treatment of sorghum stover with urea and supplementation with poultry litter on feed intake, digestibility and live weight performance of Wadara cattle. M. Sc. Thesis, University of Maiduguri, Maiduguri, Nigeria Pg 65.

Abou-EL-Enin, O.H., Fadel, J.G. and Mackill, D.J. (1999). Differences in chemical composition and fibre digestion of rice straw with, without, anhydrous ammonia from 53 rice varieties. *Animal Feed Science Technology*. 79: 129-136.

Abubakar, M., Adegbola, T.A., Abubakar, M.M., Shehu, Y., Ngele, M.B. and Kalla, D.J.U. (2010). Nutritional evaluation of different sources of nitrogen on digestible nutrient intake, nitrogen balance and production of rumen metabolites in growing Yankasa sheep. *Emirates Journal of Food and Agriculture*. 22 (4): 298-307.

Adane, Y. and Girma, A. (2008). Economic and marketing systems in Ethiopia: Significances of sheep and goats. In Alemu, Y. and Markel, R.C. Characteristics and strategies for improvement (Eds). Sheep and goats (improving productivity and market success). *Production Handbook for Ethiopia* pp 10-15.

Ademosun, A.A, Bosman, H.G. and Jansen, H.J. (1988). Nutritive studies with West African Dwarf goats in the humid tropics. In: B. Smith and H.G. Bosman (eds) Goat production in the humid tropics. Pudoc wageningen Pp 51-61.

Adeniji, A.A and Ehimere, S. (2003). Effect of replacing maize with sorghum offal in the diets of weaner rabbits. *Journal of Agricultural Research and Development* 2:1 – 6.

Adu, I.F. and Ngere, L.O. (1979). The indigenous sheep of Nigeria. *World Review of Animal Production.* Vol.15. No.3: 51-62

Adu, I.F. and Adamu A.M. (1982). The nutritive value and utilization of three tropical grass hays by sheep. *Tropical Grasslands* 16: 29-33.

Adu, I.F., Fajemisin, B.A. and Adamu, A.M. (1990). The utilization of sorghum stover fed to sheep as influenced by urea graded levels of lablab supplementation. *In: Proceedings of the First Biennial Conference of the African Ruminant* Research.

Afolayan, R.A. (1996). Lactation curve and relationship between milk yield and preweaning growth in lambs of Yankasa sheep (M.Sc. Thesis). Ahmadu Bello University, Zaria, Nigeria. Pp 52

Aganga, A.A. and Fabi, L. (2007). Performance of Tswana sheep under semi-intensive management in Gaborone, Botswana. *Research Journal of Animal Sciences,* 1(4):123 – 127.

Agbagla-Dohnani, A., Noziere, P., Gaillard-Martinie, B., Puard, M. and Doreau. M. (2003). Effect of silica content on rice straw ruminal degradation. *Journal of Animal Science*140:183-192.

Agishi, E.C. (1985).*Forage resources of Nigeria rangelands*. In Adu, I.F. Osinowo, O.A., Taiwo, B.B.A. and Alhassan, W.S. Proceedings of National Conference on Small Ruminant Production, Zaria, Nigeria. Edited by. Pp 115-140 NAPRI, Zaria. pp 115–124.

Agrawal, I.S., Verma, M.L., Singh, A.K., and Pandey, Y.C. (1989). Feeding value of ammonia (urea) treated straw in terms of milk production. *Indian Journal of Animal Nutrition* 6, 89-95.

Ahamefule, F.O., Ibeawuchi, J.A. and Ajala, A.A. (2002). Intake digestibility and nitrogen balance studies of potato peels, yeast slurry diets by West African Dwarf goats (eds) Aletor, V.A. and Onibi, G.E. *Proceedings of the 27th annual conference, Nigerian Society for Animal Production.* March 17-21, Federal University of Technology, Akure.

Ahmed, S.A. and Kibon, A. (2015). Assessment of chemical composition and rumen degradation characteristics of some crop residues and agro-industrial by-products in the Semi-arid zone of Maiduguri. *Proceedings of 20th Annual Conference of Animal Science Association of Nigeria* 6 - 10th September, 2015, Ibadan. Pp. 642-646.

Ahmed, W.M., Abou Mossallam, A.A., Hanafi, E.M. and. Shalaby, S.I. (2003). Observations on fertility and mutagenicity of Egyptian ewes exposed to products of rice straw combustion with special reference to the effect of flunixine meglumine. *Journal of Egypt Veterinary Medicine Association.* 63: 195-212.

Ajagbonna, O.P., Onifade, K.L. and Suleiman, U. (1999). Haematological and biochemical change in rats, given extracts of *Calotropis procera*. *Sokoto Journal of Veterinary Science* 1: 36 – 42.

Ajiji, I., Nyako, H.D., and Ashom, S.A. (2013). Performance of Yankasa Rams Fed *Andropogon gayanus* (Gamba Grass) Hay Supplemented with *Faidherbia albida*Acacia) Pods *Journal of Biology, Agriculture and Health care, l3*(13), www.iiste.org ISSN 2225-093X (Online).

Akande, T. (2001). An Overview of the Nigerian Rice Economy, Research paper published by the *Nigerian Institute of Social and Economic Research (NISER),* Ibadan, 11pp.

Akin, D.E., Sethuraman, A., Morrison III, W.H., Martin, S.A. and Erickson, K. (1993). Microbial delignification with white-rot fungi improves forage digestibility. *Applied Environmental Microbiology*. 59:4274-4282.

Akinfemi, A. and Ogunwole, O.A. (2012).Chemical composition and *in vitro* digestibility of rice straw treated with *Pleurotus ostreatus*, *Pleurotus pulmonarius* and *Pleurotu tuber-regium*. *Slovak Journal of Animal Science* 45(1): 14-20.

Akinsoyinu, A.O. and Onwuka, C.F.I. (1988). Mineral constituents of some browse plants used in ruminant feeding in Southern Nigeria. *Nigerian Journal of Animal Production*. 15:57-62.

Akpa, G.N., Alphonsus, S. and Abdurrashid, M. (2006). Factors affecting body size and horn length in smallholder Yankasa rams. *Savannah Journal of Agriculture* 1(2): 35-42.

Alam, M.K., Ogata, Y., Sako, Y., Al-Mamun, M. and Sano, H. (2010). Intermediary metabolism of plasma acetic acid, glucose and protein in sheep fed a rice straw-based diet. *Asian-Australian Journal of Animal Science.* 23:1333–1339.

Alli-Balogun, J.K. (2010). Effect of exogenous enzyme treatment on the nutritional value of Gamba hay (*Andropogon gayanus*, Kunth, fed to cattle. Ph. D Thesis. Deparment of Animal Science, Ahmadu Bello University, Zaria, Nigeria. Pp123.

Aman, P. and Nordkvist, E. (1983). Chemical composition and *in vitro* degradability of botanical fractions of cereal straw. *Swedish Journal of Agricultural Research.,* 13: 61-67.

Amodu, J.T. and Otaru, S.M. (2004). A training manual, National Animal Production Research Institute (NAPRI), Shika, Federal Ministry of Agriculture and Rural Development, Ahmadu Bello University, Zaria, Nigeria.

Amodu, J.T., Kallah, M.S., Lakpini, C.A.M. and Alawa, J.P. (2008). The nutritive Value of Silage made from Mixtures of Pearl millet (*Pennisetum americanum*) and Lablab (*Lablab purpureus*) as Feed for Rams. *Science alert*. AJAVA., 3:78-84.http//scialert.net/abstract/?doi=ajava.2008.78.84.

Amole, T.A., Oduguwa, B.O., Onifade, S.O., Jolaosho, A.O., Amodu, J.T. and Arigbede M.O. (2015). Effect of Planting Patterns and Age at Harvest of Two Cultivars of *Lablab purpureus* in *Andropogon gayanus* on Agronomic Characteristic and Quality of Grass/Legume Mixtures. *Pertanika Journal of. Tropical Agricultral Science*. 38 (3): 329 – 346.

Anantasook, N., Wanapat, M., Cherdthong, A. and Gunun, P. (2013). Effect of plants containing secondary compounds with palm oil on feed intake, digestibility, microbial protein synthesis and microbial population in dairy cows. *Asian-Australian Journal of Animal Science* 26:820–826.

Anele, U., Arigbede, O., Seudekum, K.H., Ike, K., Oni, A., Olanite, J., Amole, G., Dele, P. (2010). Effects of processed cowpea (*Vigna unguiculata* L. Walp) haulms as feed supplement on voluntary intake, utilization and blood profile of West African Dwarf sheep fed a basal diet of *Pennisetum purpureum* in the dry season. *Animal Feed Science Technology* 159, 10-17.

Anigbogu, N.M. and Ibe, S.I. (2005). The effect of crude enzymic residue of sawdust/poultry litter in the nutrition of West African Dwarf goats, *Proceedings of the 30th Annual Conference Nigerian Society for Animal Production,* 20th-24th March, 2005, University of Nigeria, Nsukka Pp 175-178.

ANR (Agriculture and Natural Resource) (2002). Feeding Rice Straw to Cattle, California University, Publication 8079.Available on http://www.anrcatalog.ucdevis.edu

AOAC (1990). Association of Offical Analytical Chemists, Washington, DC., USA., PP: 200;210.

AOAC(1995). AOAC International, 16th ed., Vol. 1. Agricultural Chemicals, Contaminants, Drugs, Washington, DC, USA, 521p.

AOAC. (2007). Association of Official. Analytical Chemists, Washington DC.

Aregheore, E.M., Makkar, H.P.S. and Becker, K. (1998). Feed value of some browse plants from the Central zone of Delta state, *Nigeria Tropical Sci*ence 38, 97-104.

Arieli, A. (1997). Whole cottonseed in dairy cattle feeding: a review. *Animal Feed Science Technology* 72:97-110.

Atta-Krah (1998). Fodder trees and shrubs in tropical Africa: importance, Availability and patterns of utilization. Integration of livestock with crops in response to increasing population pressure on available resources, CTA-*Seminar proceedings,* Mauritius. Pages 118-138.

Babayemi, O.J., Abu, O.A. and Opakunbi, A. (2014). *Integrated animal husbandry for schools and colleges.* First published 2014 by Positive press, Iwo road, Ibadan P. 203.

Bacon, J.S.D., Chesson, A. and Gordon, A.H. (1981). Deacetylation and enhancement of digestibility. *Agricultural Environment* 6: 115-126.

Bae, H.D., Mc Allister, T.A., Kokko, E.G., Leggett, F.L., Yanke, L.J., Jakober, K.D., Ha, J.K., Shin, H.T. and Cheng, K.J. (1997). Effect of silica on the colonization of rice straw by ruminal bacteria. *Animal Feed Science Technology*. 65:165-181.

Baile, C.A. and Forbes, J.M. (1974). Control of feed intake and regulation of energy balance in ruminants. *Physiology Review*.54:160-214

Banerjee G.C. (2007). *A text Book of Animal Husbandry*. 8th edn. Published by Raju primlani for Oxford and IBH publishing Co. Pvt. Ltd. New Delhi. Pp 357

Ben, A. (2002). Marketing of Small Ruminants in Nigeria. In: Lakpini, C.A.M., Adamu, A.M., Ehoche, O.W. and Gefu, J.O. (eds). Manual for Small Ruminant Production in Nigeria Workshop at National Animal Production Research Institute, Ahmadu Bello University, Shika, Nigeria 13th -18th January, Pp 77-85.

Braun,V.J. (2006). Public policy and international collaboration for sustaining and expanding the rice revolution. Paper presented at the international rice congress on science, technology and trade for peace and prosperity, New Delhi October 9-13th 2006.

Buvanendran, V. and Adu, I.F. (1990). Balami Sheep: Performance in North-Eastern Nigeria. *Nigerian Journal of Animal Production* – Vol. 17, No 1.

Calzado, J.F. and Rolz, C. (1990). Estimation of the growth rate of Pleurotus on stocked straw. *Journal of Fermentation Bioengetics*. 69: 70-71.

Cao, Y.F., Li, Y., Liu, R.C., Liu, G.Y., Li, J.G., Pi, R.Y., and Feng, L.M. (2000). Effect of chemical complex treatment on growth performance of beef cattle. *China Herbivores*, 2(1): 13-16.

Carew, B.A.R., Mosi, A,K., Mba and Egbunike, G.N. (1989). The potential of browse plants in the nutrition of Small Ruminants in the Humid Forest andDerived Savannah Zones of Nigeria In: *Browse in Africa the current state of knowledge*. ILCA, Addis Ababa. Pp. 307-311.

Chowdhury, A.S. and Miller, E.L. (1996). The effect of sodium hydroxide and alkaline hydrogen peroxide on chemical composition of wheat straw and voluntary intake, growth and digesta kinetics in store lambs. *Animal Feed Science Technology.* 60:69-86.

Chowdhury, A.S. and Huque, K.S. (1996). Study on the development of a technique for preserving straw under wet condition in Bangladesh. *Asian –Australian Journal of Animal Science*. 9: 91-99.

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

Chenost, M. (1995). Optimizing the Use of Poor Quality Roughage through Treatments and Supplementation in Warm Climate Countries with Particular Emphasis on Urea Treatment. First Electronic Conference on Tropical Feeds with Particular Emphasis on Urea Treatment. FAO, Rome.

Chenost, M. and Kayouli, C. (1997). Roughage Utilization in Warm Climates. FAO Animal and Health Paper 135. Rome.

Chesson, A. and Orskov, E.R. (1984). Microbial degradation in the digestive tract. In: F. Sundstol and E. Owens (eds), *Straw and other fibrous byproducts as feeds.* Elsevier Science Publishers, Amsterdam, The Netherlands. pp. 305–339.

Chesson, A. and Forsberg, C.W. (1988). Polysaccharide degradation by rumen microorganisms p. 251–284. *In:* P. N. Hobson (ed.). The rumen microbial system. Elsevier AppliedSci., New York, N.Y.

Chetna Bhatt, R.S., Jaiswal, T.C. and Joshi, Y.P. (2004). Effect of urea treated baled wheat straw based diets on the performance of crossbred heifers. *Indian Journal of Animal Nutrition* 21:236-239.

Cheva, I.B. and Jaerachai, K. (1987). A comparison of urea treated rice straw with urea molasses sprayed rice straw as basal diet for growing cattle. *In:* Ruminant Feeding System Utilising Fibrous Agricultural Residue. Pp 121

Clay, P.M. (2000). Sheep production and management New Mexico state University

Coles, E.H. (1986). *Veterinary Clinical Pathology*. 4th Ed. W.B. Saunders, Philadelphia. PP: 11-41, 114-121.

Croston, D. and Pollot, G.E. (1994): *Plan sheep production*, 2nd edition, Blackwell Scientific Publication, Australia, pp 109-120.

Dahiya, S.S. Mudgal, V.D. and Gupta, R. (1990). Nutrient utilization, quality and quantity of milk produced by buffaloes fed treated wheat straw based ration. *Indian Journal of Animal Science* 5:215-220.

Daniel, J.D., Glenn, N. and Larry, F. (2002). Feeding rice straw to cattle. Publication 8079 University of California Division of Agriculture and Natural Resources http://anrcatalog.ucdavis.edu

Daren, C.W., Datnoff, L.E., Snyder, G.H., and Martin, F.G. (1994). Silicon concentration, disease response, and yield components of rice genotypes grown on flooded organic histosols. *Crop Science* 34,733-737.

Devendra, C. (1971). The comparative efficiency of feed utilization of ruminants in the tropics.*Tropical Science*13:123-132.

Devendra, C. (1982). Perspectives in the utilization of untreated rice straw by ruminants in Asia. In: " The utilization of fibrous agricultural residues as animal feeds". Pp. 7-26 (Editor: P.T. Doyle). School of Agriculture and Forestry, University of Malbourne. Parkville,Vic.

Devendra, C. (1997). Crop residues for feeding animals in Asia: Technology development and adoption in crop/livestock systems. In: Crop Residuals in Sustainable Mixed Crop/livestock Farming System (Ed. C. Renard). CAB International; Wallingford, UK. pp. 241-267.

de Leeuw P.N. (1979). A review of ecology and fodder resources of the sub-humid zone. Paper presented at ILCA/NAPRI Conference, Kaduna.

Diarra B. (1983). *Effect of ammonium hydroxide treatment on digestibility of nutrients in soybean straw by steers*. Master of science thesis. Agricultural and Mechanical University, Alabama, USA, 44 p.

Dias-da-Silva, A.A., and Guedes, C.V.M. (1990). Variability in the nutritive value of straw cultivars of wheat, rye and triticale and response to urea treatment. *Animal Feed Science Technology* 28, 79-89.

Dicko, M.S. and Sikena, L.K. (2003). Fodder trees and shrubs in range and farming system in dry tropical Africa. http://www.smallstock.info/reference/FAO/003/T0632E/T0632E03.htm retrieved on 6thMarch, 2012.

Dixon, R.M. (1987). Maximising the rate of fibre digestion in the rumen. In: Ruminant Feeding Systems Utilizing Fibrous Agricultural Residues (Ed. R.M. Dixon), IDP, Canberra, Australia. pp. 59-75.

Dobermann, A. and T.H. Fairhurst, T.H. (2002). Rice Straw Management. *Better Crops International* Vol. 16, Special Supplement.

Doble, J.B. and Walker, Jr.H. (1977). Effect of NaOH and NH_3 on curability and digestibility of rice straw, *Trans. ASAE*. 20 (60): 1018-1021.

Dolberg. F, Saadullah, M., Haque, M, Ahmed, R. and Haque, R. (1980). Different ways of keeping straw during treatment with urea as a source of ammonia using indigenous material for storage - including some observations on temperature and treatment time Paper accepted for presentation at First Asian Australasian Livestock Congress Malaysia.

Doyle, P.T., Devendra, C. and Pearce, G.R.(1986). Rice straw as a feed for ruminants. International Development Program of Australian Universities and Colleges Limited (IDP), Canberra, Australia.

Doyle, P.T., Pearce, G.R. and Djajanegara, A. (1987). Intake and digestion of cereal straws. In: *Proceedings of the 4th Animal Science Congress*, held in Hamilton, New Zealand. Fourth Congress.

Drake, D. J., Nader, G. and Forero, L. (2002). Feeding rice straw to cattle. Publication 8079 - University of California, Division of Agriculture and Natural Resources. 2002

Duncan, D.B. (1955). Multiple Ranges and Multiple F- Tests *Biometric*s, 11:1-420.

Dutta, N., Sharma, K. and Hassan, O.Z. (1999). Effect of supplementation of rice straw with *Leucaena leucocephala* and *Prosopis cineraria* leaves on nutrient utilization by goats.

Dutta, N., Sharma, K. and Naulia, U. (2004). Nutritional evaluation of lentil (*Lens culinaris*) straw and urea treated wheat straw in goats and lactating buffaloes. *Asian-Australian Journal of Animal Science* 17:1529–1534.

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

Ehoche, O.W. (2002). Feeding strategies for improving milk production. in: Fanimo, A.O. and Olanife, J.A. (Eds) contributory role of animal production in national development. *Proceedings of the 7th Annual Conference of the Animal Science Association of Nigerian* (ASAN), Abeokuta, Nigeria. Pp.19-26.

Ekanem, N.J. (2012). Silage characteristics and performance of Red Sokoto goats fed cassava peels ensiled with brewers dried grains and poultry litter M.Sc. thesis submitted to the Department of Animal Science, Faculty of Agriculture, University of Ibadan. Pp 79

El-Shobokshy, A.S., James, D.I.H., Marai, I.F.M., Owen, J.B. and Philips, C.J.C. (1989). New techniques in feed processing for cattle. In: New Techniques in Cattle Production. (Eds) C.J.C. Philips. Butterworth and Co (Publishers) Ltd., pp. 67-86.

Emtenan, M.H., El Khadrawy, H.H., Ahmed, W.M. and Zaabal, M.M. (2012). Some observations on Rice Straw with Emphasis on Updates of its Management. *World Applied Sciences Journal* 16 (3): 354-361,

Fadel Elseed, A.M.A., Sekine,J. Hishinuma,M. and Hamana,K. (2003). Effects of ammonia, urea plus calcium hydroxide and animal urine treatments onchemical composition and *in sacco* degradability of rice straw. *Asian-Australian Journal of Animal Science* 16: 368-373.

Fadiyimu, A.A., Fajemisin, A.N., Folorunso, O.R., Adeyeye, S.A. and Sule, K. (2015). Nutrient intake and digestibility in west in west African Dwarf Goats fed *Persea americana* leaves as supplement to Panicum. *Proceedings of 40th Annual Conference, Nigerian Society for Animal Production*, 15-19th March, 2015, NAPRI/ABU, Zaria. Pp

Fall, S., Guerin, H., Sall, C. and Mbaye, N.D. (1989). Cereal straws in the feeding system of ruminant in Senegal. Overcoming constraints to the efficient utilization of agricultural byproducts as animal feed. In: Adegbola, A.A., J.A. Kategile and D.A.

FAO (Food and Agriculture Organization of the United Nations). (1985). *Production Yearbook, Volume 39.* Food and Agriculture Organization: Rome, Italy.

FAO (Food and Agriculture Organization of the United Nations). (1991). *Animal Production and Health paper 88*. Food and Agriculture Organization of the United Nations:Rome, Italy.

FAO (Food and Agriculture Organization of the United Nations). (2002). Animal Production Based on Crop Residues; China's Experiences. *FAO Animal Production and Health Paper*. No. 149. 39p.

FAO (Food and Agriculture Organization of the United Nations). (2007). State of the world's animal genetic resources for food and agriculture.

FAO (Food and Agriculture Organization of the United Nations). (2008). *Production Year Book*. Food and Agriculture Organization. Rome,Italy.

FAO (Food and Agriculture Organization of the United Nations) (2012). Global rice paddy production and area.

FAO (Food and Agriculture Organization), (2013). FAO Statistics on crop production estimate in Nigeria. www.faostat3.org.

Farghly, M.S. (1993). Biological or chemical treatment of rice straw for ruminant nutrition. Ph.D Thesis, Faculty of Agriculture, Cairo University. Pp 169.

FDLPCS (1992). Federal Department of Livestock and Pest control Services. Nigeria Livestock resources vol. II Natural Synthesis Resources Inventory and Management Ltd. St.Helier, Jersey, U.K.

Feng, Y.L. (1996). Some advances in ruminant animal nutrition in China. p. 128-137,*In: Proceedings of 1st China/Korea Joint Symposium on Recent Advancesin Animal Nutrition and Feed Technology*. Beijing, 18-29 June 1996.

Finangwai, H.I. Ehoche, O.W. and Akpa, G.N. (2008). Effect of urea treated maize stover based complete diet o intake and growth rate of Friesian x Bunaji Bull. In: Jokhtan and Abdu, S.B. (Eds). Repositioning Animal Agriculture for Realization of National Vision 2020. *Proceedings of 13th Annual Conference* of *ASAN Held in A.B.U., Zaria,* Nigeria 19th-24th September, 2008.

Finangwai, H.I. Ehoche, O.W. and Akpa, G.N. (2010). Effect of urea treated maize stober based complete diet on the biochemical changes in the rumen and blood parameters of Friesian x Bunaji Bull. In: Ifut, O.J., Inyang, U.A., Akpan, P.I. and Ebeso, I.E. (Eds). Diversifying Nigeria'sEconomy. Animal Production option. *Proceedings of the 15th Annual conference held in Uyo*, Nigeria, 13-16 September, 2010.

Finangwai, H.I. and Dafur, B.S. (2015). Evaluation of urea treated Acha (*Digiteria exilis*) straw on dry matter intake, growth and body measurement of growing Yankasa RAMS. *Proceedings of 20th Annual Conference of ASAN Held in Ibadan,* Nigeria 6th-10th September, 2015.

Fitzhugh, H.A. (1978). Bio-economic analysis of ruminant production systems. *Journal of Animal Science* 46: 797-806

FMARD (2016). Federal Ministry of Agriculture and Rural Development. Retreat on Livestock and Dairy Development in Nigeria – Keynote address Delivered by the Hon. Minister of Agriculture and Rural Development, Chief Audu Ogbeh June 7, 2016. (http://fmard.com.ng/?feed=rss)

Francis, P.A. (1988). Livestock and farming Systems in South-East Nigeria In: Smith, B. and Bosman, H.G. (eds) *Goat production in the Humid Tropics*. Pudoc Scientific Publishers. Wageningen. The Netherlands PP 159-169.

Frandson, R.D. (1986). Blood and other body fluids. In: *Anatomy and Physiology of Farm Animals*, 4th ed. Lea and Ferbiger, Philadelphia, pp. 233-257.

Fuglie, I. (1991). Producing food without pesticides, Local solution to crop pest control in West African, Centre for Technical Agricultural and Rural Cooperation (Ede NetherLands).

Galo, E., Emanuele, S.M., Sniffen, C.J., White, J.H. and Knapp, J.R. (2003). Effects of a polymer-coated urea product on nitrogen metabolism in lactating Holstein dairy cattle. *Journal of Dairy Science* 86:2154–2162.

Garba, Y. and Muhammad, I.R. (2008). Sabara (*Guiera senegalensis*) as browse and potential Milk Enhancer in semi-Arid environment. *Research Journal of Animal Science* 2(4): 123-127.

Garba, Y. and Ado, N.S. (2015). Feed intake and nutrient digestibility by Uda rams fed graded levels of Anogeissus leiocarpus. *Proceedings of 20th Annual Conference Animal Science Association of Nigeria* 6 - 10th September, 2015, Ibadan. Pp697-701.

Gatenby, R.M. (1985*). Sheep Production in the Tropics and Subtropics*. Longman Group Ltd. Longman House, Harlow Essex, England. pp 56 – 57.

Gefu, J.O. and Adu, I.F. (1982). Observations on the herd size of sheep and goats in Kano state Nigeria. *World Review of Animal Production* xviii. (2): 25-28.

Givens, D.I., Adamson, A.H. and Cobby, J.M. (1988). The effect of ammoniation on the nutritive value of wheat, barley and oat straws: Digestibility and EnergyValue Measurements *in vivo* and Their Prediction from Laboratories Measurements. *Journal of Animal Feed Science and Technology* 19 (1-2): 173-184.

Givens, D.I. and Moss, R. (1993). A review: The nutritional value of cereal straws for ruminants. Nutritiona Abstract Review. 65:793-811.

Goto, M. and Yokoe, Y. (1996). Ammoniation of barley straw. Effect on cellulose crystallinity and water-holding capacity. *Animal Feed ScienceTechnology* 58:239–247.

Greenhalgh, J.F.D. (1984). Upgrading crop and agricultural by-products for animal production. In: Gilchrist, F.M.C. and Mackie, R.I. (eds), *Herbivore Nutrition in the Subtropics and Tropics*. The Science Press, Pretoria, South Africa. pp. 167-184.

Gunun, P. and Wanapat, M. (2012). Effect of physical form of urea-treated rice straw on nitrogen balance, rumen fermentation and nutrient digestibility in dairy steers. *Khon Kaen Agriculural Journal.* 2012; 40(Suppl.):62–68.

Gunun, P., Wanapat, M. and Anantasook, N. (2013). Rumen Fermentation and Performance of Lactating Dairy Cows affected by Physical Forms and Urea Treatment of Rice Straw. *Asian-Australian Journal of Animal Sciences* 26(9): 1295-1303.

Gupta, B.N., Singh, G.P. and Singh, K. (1993). Biological treatment of ligno-cellulosics as feed for animals-an overview. In: Kiran Singh and J.B. Schiere. (Eds). Feeding of ruminants on fibrous crop residues. *Indian Council of Agricultural Research,* Krishi Bhavan, New Delhi. pp. 209-221.

Ha, J.K., Lee, S.S., Kim, S.W., Han, K., Ushida, K. and Cheng, K.J. (2001). Degradation of rice straw by rumen fungi and cellulolytic bacteria through mono- co- or sequential-cultures. *Asian-Australian Journal of Animal Science* 14:797–802.

Hadjipanayiotou, M., (1984). Effect of level and type of alkali on the digestibility *in vitro* of ensiled, chopped barley straw. *Agricultural Wastes,* 10: 187-194.

Hamzat, R.A., Omole, A.J., Babatunde, B.B., Adejumo, M.O. and Longe, O.G. (2007). Comparative value of kola testa, corn-bran with maize for mature African giant land snail. (*Archachatina marginata*). *Nigeria Journal of Animal Production*, 34 (2): 265-276.

Han, I.K. and Ha, J.K. (1989). The energy value of rice straw for ruminants as influenced by treatment with anhydrous ammonia or mixing with alfalfa *AJAS* 2(2): 115-121.

Hanafi, E.M., EL Khadrawy, H.H., Ahmed, W.M. and Zaabal, M.M. (2012). Some observation on rice straw with emphasis on updates of its management. *World Applied Science Journal* 16:354-361.

Hang Le Thi Thuy (2003). Fresh rice straw treated with urea and lime as feed for dairy cattle in An Giang province,Vietnam (http://www.mekarn.org/msc200305/theses05/thuyh_lit.pdf)

Hart, F.J. and Wanapat, M. (1992)**.** Physiology of digestion of urea treated rice straw in swamp Buffalloes. *Asian-Australian Journal of Animal Science* 5:617-620.

Hartley, R.D. and Jones, E.C. (1978). Phenolic compounds and digestibility of cell walls of the brown midrib mutants. *Journal of Science and Food Agriculture* 29: 777-789.

Hassim, H.A., Lourenc, M., Goh, Y.M., Baars, J.J.P. and Fievez, V. (2012). Rumen degradation of oil palm fronds is improved through pre digestion with whitefungi but not through supplementation with yeast or enzymes. *Canadian Journal of Animal Science* 92:79–87.

Hatfield, R.D., J. Ralph, and Grabber, J.H. (1999).Cell wall structural foundations: molecular basis for improving forage digestibilities. *Crop Science* 39:27–37.

Henry, R.J. and Stobel, C. (1957). Determination of serum protein by burette reaction. *Analytical Chemitry*, 92:1491.

Henzell, E.F. and Manntje, L.T. (1980). Grassland and forage research in tropical and sub-tropical climate. In*: Perspectives of world agriculture*. CAB. Pp. 485-532.

Heuze, V., Tran, G. (2013). Rice straw. Feedipedia.org. A programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/557 *Last updated on March 15, 2013, 14:12.*

Heuze, V., Tran, G. (2015). Rice straw. Feedipedia.org. A programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/557 *Last updated on October 5, 2015, 11:33.*

Hoffmann, I. (2002). Crop-livestock interactions and soil fertility management in northwest Nigeria. *First Virtual Global Conference on Organic Beef Cattle Production.* September, 02 October, 15 2002 Via Internet, 11pp.

Hogan, J.P. Kenny, P.A. and Weston, R.H. (1986). Factors affecting the intake of feed by grazing animals. In: J.M. Wheeler, C.J. Pearson and G.E. Robards (eds), Temperate pastures, their production, use and management. *Proceedings of a Conference held at Leura, New South Wales,* December 1985. Australian Wool Corporation/CSIRO, Australia.

Horton, G.M.J., F.M. Pate and W.D. Pitman, (1991).The effect of steam-pressure treatment, pelleting and ammoniation on the feeding value of sugarcane bagasse for cattle. *Canadian Journal of Animal Science* 71: 79-86.

Hossain, S.M.J., Adam, M.R., Sultana, N., Anim, M.R. and Rashid, M.M. (2004). Milk production from indigenous black Bengal Goat in Bangladesh. *Journal of Biological Science* 3(3) 262-265.

Hozein, H.F., (2011). Some physiological changes associated with exposure to air pollution in cows with special emphasis on ovarian activity, M.V.Sc. Thesis (Physiology), Cairo University, Egypt.

http://agriculturenigeria.com/farming-production/livestock/sheep).Sheep production- Agriculture Nigeria

Humphreys, L.R (1991). *Tropical pasture utilization*. Cambridge: Cambridge UniversityPress.

Huston, J.E., Engdahl, B.S. and Bales, K.W. (1988). Intake and digestibility in sheep and goats fed three forages with different levels of supplemental protein. *Small Ruminant Research.*1, p. 81–92.

Ibhaze, G.A., Alade, C.T., Fajemisin, A.N., Olorunnisomo, O.A., Adewumi, M.K., Ekeocha, A.H., Tona, G.O. (2015). Quality and preference of *Gmelina arborea* leaves and cassava peel silage as off season feed for West African Dwarf goats. *Proceedings of 20th Annual Conference Animal Science Association of Nigeria* 6 - 10th September, 2015, Ibadan. Pp. 688-691.

Ibrahim, M.N.M. (1981). Physical, chemical, physico-chemical and biological treatments of crop residues. An overview. In: The Utilization of Fibrous Agricultural Residues (Ed.G.R.).

Ibrahim, M.N.M., Ketelaar, R.S., Tamminga, S. and Zemmelink, G.(1987). Degradation characteristics of untreated and urea-treated rice straw in the rumen. *In* RM. Dixon, ed. Ruminant feeding systems utilizing fibrous agricultura lresidues. *Proceedings of the Seventh Annual Workshop of the Australian-Asian Fibrous Agricultural Residues R e s e a rch Network held at Chiang Mai University, Thailand*, p. 123–126.

Ibrahim, M.N.M. and Schiere, J.B. (1989). Feeding of Urea-Ammonia Treated Rice Straw. A Compilation of Miscellaneous Reports Produced by the Straw Utilization Project (Sri Lanka). Wageningen. pp.1-28.

Ikhatua, U.J. (2000). The Nigerian Livestock Industry – A sleeping giant? Paper presented at the 56th of the University of Benin series of inaugural lectures.

ILCA (1979). *Small ruminant production in the humid tropics.* Systems Study No. 3. *International Livestock Centre for Africa,* Addis Ababa, Ethiopia.

ILCA (1982). International Livestock Centres for Africa. Small ruminant production in the tropics. ILCA, Addis Ababa, Ethiopia.

ILCA (International Livestock Centre for Africa), 1993. Feed evaluation, ILCA Manual 5, Osuji, P.O., Nsahlai, I.V. and Khalili, H. (Eds.). Addis Ababa, Ethiopia, 40pp.

Ipharraguerre, I.R., Clark, J.H. and Freeman, D.E. (2005). Varying protein and starch in the diet of dairy cows. Effects on ruminal fermentation and intestinal supply of nutrients. *Journal of Dairy Science* 88, 2537-2555.

Isah, O.A., Ijiyemi, A.V., Ajayi, O.A., Afolabi, B.E., Talabi, J.O.K., Omolabi, O.A. and Akinbode, R.M. (2015). Morphological identification of rumen microbial isolate and rumen metabolites of West African Dwarf sheep supplemented with forage-based multi-nutrient block. *Journal, Nigerian Society for Animal Production* 42(1), 143-156.

Jabbar, M.A., Muzafar,H., Khattak,F.M., Pasha,T.N. and Khalique, A. (2009). Simplification of urea treatment method of wheat straw for its better adoption by the farmers.*South African Journal of Animal Science* Vol.39 no.5 Pretoria 2009.

Jackson, M.G. (1977). Review article: The alkali treatment of straw. *Animal Feed Science Technology* 2:105-130.

Jackson, M.G. (1979). Rice straw as livestock feed In: Ruminant nutrition, *World Animal Review:* 34-40. FAO, Rome

Jackson, (2010) http://www.feedipedia.org/node/557). Accessed 20thJuly, 2013.

James, U. (2011). Much ado about rice production. Publication of Nigeria Newsworld http://www.nigeriannewsworld.com/content/much-ado-about-rice- production

Jayasuriya, M.C.N. and Perera, H.G.D. (1982). Urea-ammonia treatment of rice straw to improve its nutritive value for ruminants. *Agricultural Wastes* 4:143-150.

Jayasuriya, M.C.N. Perdok, H.B., Ross-Parker, H.M. and van Houtert, M.F.J. (1982a). Effect of alkali-treated rice straw supplemented with spent tea leaf and thyroprotein on milk yield, milk composition and certain physiological parameters of dairy cows. *Animal Feed Science Technology.* 7:201-216.

Jayasuriya, M.C.N., Haminton, R. and Rogovic, B. (1987). The use of an artificial rumen to assess low quality fibrous feeds. *Biological Waste.* 20:241-250.

Jenkins, B.M. and Bhatnagar, A.P. (2003). On electric power potential from paddy straw in Punjab and the optimal size of the power generation station. *Biological Resources Technology* 37, 35-41.

Jess, D.R. and Michael, R.G. (1989). Estimating the nutritive value of cereal crop residues: Implications for developing feeding standards for draught animals

Juliano, B.Q. (1988). Effect of silica level on some properties of rice plant and grain. In: Dixon, R. M. (ed.), *Proceedings of a Workshop on Ruminant Feeding Systems Utilizing Fibrous Agriculture Residues*. International Development Program of Australian Universities and Colleges (IDP), Canberra, pp. 115- 122.

Jung, H.G. (1989). Forage lignins and their effects on fibre digestibility. *Agronomy Journal.* 81:33.

Jung, H.G., Buxton, D.R., Hatfield, R.D. and Ralph, J. (1993). Forages cell wall structure and digestibility. American Society for Agronomics, Wisconsin, USA.

Jung, H.G. and Deetz, D.A. (1993). Cell wall lignifications and degradability. In: H.G. Jung, *et al*. (eds.). Forage Cell Wall Structure and Digestibility. ASA-CSSA-SSSA, Madison,Wisconsin. p. 315-346.

Jung, H.G. and Allen, M.S. (1995).Characteristics of plant cell walls affecting intake and digestibility of forages by ruminants. *Journal of Animal Science* 73:2774–2790.

Kadam, K.L., Forrest, L.H., Jacobson, W.A. (2000). Rice straw as a lignocellulosic resource: collection, processing, transportation and environmental aspects. *Biomass and Bioenergy* 18: 369-389.

Kaitho. R.J., Nsahlai, I.V., Williams, B.A., Umunna,N.N., Tamminga, S. and Van Bruchem, J. (1998). Relationship between preference, rumen degradability, gas production and chemical composition of browses. *Agroforest Systems.* 39: 129-144.

Kallah, M.S., Baba. M., Alawa, J.P., Muhammad, I.R. and Tanko, R.J. (1997). Ensiling Quality of Columbus Grass (*Sorghum alamum*) Grown in the Northern Nigeria. *Animal Feed ScienceTechnology* 68: 153-163.

Kalio, G.A., Agwunobi, L.N., Ayuk, A.A. and Eneji, C.A. (2013). Availability and estimation of crop by-product yields for small ruminant production in Cross River State, Nigeria. *Nigerian Journal of Animal Production,* 40: 117-122.

Kaneko, J.J. (1989). *Clinical biochemistry of domestic animals*, ed 4, New York, 1989, Academic Press.

Keller, F.A., Hamillton, T.E. and Nguyon, Q.A. (2003). Microbial pretreatment of biomass potential for reducing severity of thermo-chemical biomass pretreatment. *Applied Biochemical Biotechnology*. 105:27–41.

Kennedy, P.M. (1982). Ruminal and intestinal digestion in Brahman crossbred and Hereford cattle fed alfalfa or tropical pasture hay. *Journal of Animal Science.* 55:1190-1199.

Kerchgessner, M., Windisch, W. and Roth, F.X. (2001). The efficiency of nitrogen conversion in animal nutrition. *Journal of Animal Science,* 79: 247-253.

Keshtkar, H. and Ashbaugh, L.L. (2007). Size distribution of polycyclic aromatic hydrocarbon particulate emission factors from agricultural burning. *Atmospheric Environmental Journal* 41: 2729-2739.

Khejornsart, P. and Wanapat, M. (2010). Effect of chemical treatment of rice straw on rumen fermentation characteristic, anaerobic fungal diversity *in vitro*. *Journal of Animal Veterinary Adv.* 9:3070-3076.

Kling, S.H., Carvalho, N.C., Ferrara, M.A., Torres, J.C.R., Magalhaes, D.B. and Ryu, D.D. (1987). Enhancement of enzymatic hydrolysis of sugarcane bagasse by steam explosion pre-treatment. *Biotechnology and Bioenergetic*. 29: 1039.

KNARDA (Kano Agricultural and Rural Development Authority) (2001). *Metrological Station Reports Temperature Record Book and Management Unit* No. 11:1-3

Koney, E.B.M. (2004). *Livestock production and health in Ghana,* Second edition. Advent press, Accra, Ghana, pp. 38-44.

Kossila, V.l. (1985). Global review of the potential use of crop residues as animal feed. In FAO Animal Production and Health Paper 50, 1-13. FAO Rome.

Lakpini, C.A.M. (2002). Feeds and feeding strategies for small ruminants in various physiological states. In: Lakpini, C.A.M., Adamu, A.M., Ehoche, O.W. and Gefu, J.O.N. (eds). *Manual for small Ruminant Production in Nigeria*. Workshop at National Animal Production Research Institute, Ahmadu Bello University, Zaria.

Lamb, G.N. (1991). *Manual of veterinary laboratory technique* CoBA- GEIGY Kenya Pp 98-99.

Lambert, M.G., and Litherland, A.J. (2000). A practitioner's guide to pasture quality. *Proceedings of the New Zealand Grassland Association, 62,* 111–115.

Lamorde, A.G. (1993). Technology transfer and livestock development in Nigeria. In: Technology transfer in national development. *Proceedings of the 5th national CODRI Seminar held at NAERLS, Zaria* on Nov. 11, 1993. Pp 34-65.

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

Lazzarini, I., Detmann, E. and Sampaio, C.B. (2009). Degradation dynamics and gives in transit detergent fiber *neutron embovino salimentados* of tropical forage with low quality and nitrogen compounds. *Brazilian Archives of Veterinary Medicine and Animal Science*, *61*, 635–647.

Leeuw, P.N.de. (1979). A review of the ecology and fodder resources of the sub- humid zone. A paper presented at ILCA/NAPRI conference, Kaduna, Nigeria.

Lemieux, P.M., C.C. Lutesb, C.C. and Santoiannib, D.A. (2004). Emissions of organic air toxics from open burning: A comprehensive review. *Programme of Energy Combustion Science* 30: 1-32.

Leng, R.A. (1997). Tree foliage in ruminant nutrition. FAO Animal Production and Health Paper 139. FAO Rome, Italy.

Leng, R.A. and Nolan, J.V. (1984). Nitrogen metabolism in the rumen. *Journal of Dairy Science.* 67: 1072 –1089.

Liu, J.X., Wu, Y.M., Dai, X.M., Jun Yao, Zhou, Y.Y. and Chen, Y.J. (1995). The effects of urea-mineral lick blocks on the liveweight gain of local yellow cattle and goats in grazing conditions. *Livestock Research Rural Development,* **7**(2): 9-13.

Liu, J.X., Chen, Z.M., Yu,J.Q. Fei,B.R.,Wang,W.D. and Zhang, J.F. (1998). Effect of ammonium bicarbonate treatment and rapeseed meal supplementation on growth rate of Huzhou lambs receiving rice straw. *Livestock Research for Rural Development* 10 (2): 2.

Liu, J.X., Orskov, E.R and Chen, X.B.(1999). Optimization of steam treatment as a method for upgrading rice straw as feeds. *Animal Feed Science Technology.*76:345-357.

Liu, J.X. and Orskov, E.R. (2000). Cellulase treatment of untreated and steam pre-treated rice straw-effect on *in vitro* fermentation characteristics. *Animal Feed Science Technology* 88:189-200.

Lombin, L. (2007). Analyzing news about African Agriculture. Retrieved on 02/10/2010. In: characterization of Sheep and Goats keepers in Katsina metropolis and survey of rumen impaction in slaughtered sheep and goats at Katsina Abattoir. An MSc. Seminar paper submitted to the Department of Animal Science, Bayero University, Kano, July, 2010.

Lufadeju, E.A., Blacket, G.A. and Orskov, E.R. (1985). The effect of variety of spring barley straw and ammonia treatment on nutritive value. *Proceedings of Nutrition Society,* 44:96.

Lufadeju, E.A. (1988). Evaluation of improving utilization of mature Gamba hay *(Andropogon gayanus)* by Friesian-Bunaji heifers. Ph D. Thesis. Deparment of Animal Science, Faculty of Agriculture. Ahmadu BelloUniversity, Samaru, Zaria, Nigeria. Pp 116

Madsen, J., Hvelplund, T., Weisbjerg, M.R. (1997). Appropriate methods for the evaluation of tropical feeds for ruminants. *Animal Feed Science Technology* 69:53-66.

Mahadevan, P. (1983). A review of the current status and problems of swamp buffalo production. In. Current Development and Problems in Swamp Buffalo Production. (Ed. H. Shimizu). *Proc. Preconference Symposium of the 5th World Conference on Animal Production*. Tusukuba, Japan, 198, Pp. 3–17.

Mahesh, M.S. and Madhu Mohini (2013). Biological treatment of crop residues for ruminant feeding: A review *African Journal of Biotechnology.* 12(27):4221-4231.

Maijala, K. (1997). Genetic aspects of domestication, common breeds and their origin. In: Piper, L. and A. Ruvinsky (eds.). The genetics of sheep. CA breeds as of 1995

Males, J.R. (1987). Optimizing the utilization of cereal crop residues for beef cattle. *Journal of Animal Science.* 65 : 1124–1130.

Man, N.V. and Wiktorsson, H. (2001). The effect of replacing grass with urea treated fresh rice straw in dairy cow diet. *Asian-Australian Journal of Animal Science,* 14(8): 1090-1097.

Mandal, L. (1997). Nutritive value of tree leaves of some tropical species for goats. *Small Ruminant Research.* 24:95-105.

Mannetje, L. (1999). Introduction to conference on silage making in the tropics in Mannetje (Ed.). Silage making in the tropics with particular emphasis on smallholders. FAO. Plant Production and Protection. Paper 161.

Mao, H.M. and Feng, Y.L. (1991). Treatment of crop residues with combination of urea and calcium hydroxide to improve their nutritional value. *Chinese Journal of Animal Science*, 27(5):3-5.

Mapato, C., Wanapat, M. and Cherdthong, A. (2010). Effect of urea treatment of straw and *Health Production* 42:1635–1642.

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

Massaguer, A., Perez-el-pulgar. S., Engel, P. and Serratosa, J. (2002). Concanavalin-A-induced liver injury is severely impaired in mice deficient in *Pselectin. Journal of Leukoc. Biology* 72: 262-270.

Mason, I.L. (1996). *A World Dictionary of Livestock Breeds, Types and Varieties*. Fourth Edition. C.A.B International. 273 pp.

McDowell, L.R. (1985). Nutrition of grazing ruminants in warm climates. Academic Press Inc., New York pp.

McDonald, R.A., Greenhalgh, J.F.D. and Morgan (1995). Animal Nutrition (5^{th} edition). Pearson Education Limited, Edinburg gate. Garlow Essex CM2O 2JE, United Kingdom.

Meng, Q.X. (1990). Upgrading utilization of roughage including crop residues in ruminant production. *Hebei Journal of Animal Science. Veterinary Medicine,* 1:52-55.

Meng Q.X. (2002). Nutritive value and upgrading of crop residues in: Animal Production Based on Crop Residues - Chinese Experiences. *Animal production and health paper* 149 FAO (2002)

Merck Veterinary Manual (2016). *The Merck Veterinary Manual* 11^{th} Edition published by Merck and Co., INC. Whitehouse station, N.J. USA in cooperation with Merial limited. A Merck and Aventis company

Mertens, D.R. (1994).Regulation of forage intake. In G.C. Fahey, Jr. (ed.) Forage Quality, Evaluation, and Utilization. ASA, CSSA, SSSA, Madison, Wisconsin. p. 450-493.

Midau, A., Mubi. , A.A. and Kwaji, Z. (2015). Evaluation of chemical composition of treated and untreated rice straw using urea. *Scientific Journal of Animal Science.*Vol. 4(12) (2015). www.sjournal.com/index.php/SIAS/issues/view/458.

Miles, E.H. and McDowell, L.R. (1983). Mineral deficiencies in the Llanos rangelands of Colombia. *World Animal Review*, 46: 2-10.

Mirzaei-Aghsaghali, A. and Maheri-Sis, N. (2008). Nutritive value of some agro-industrial by products for ruminants - A review. *World Journal of Zool*ogy 3, 40-46.

Mohamed-Salem, M.A. (1994). Evaluation of Stylosanthes for pasture development. An overwiew of ILCA'S experience in Nigeria. In: Stylosanthes as a forage and fallow crop, P.N. deLeeuw, M.A. Mohamed-Salem and A.M. Nyamu (eds). *Proceedings of Regional Workshop on the use of Stylosanthes in West Africa* held in Kaduna, Nigeria, 23-31 October 1992 pp. 17 -23.

Moore, K.J., Vogel, K.P., Hopkins, A.A., Pedersen, J.F. and Moser, L.E. (1993). Improving the digestibility of warm-season perennial grasses. *Proceedings* XVI *International Grassland Congress* p. 447–448.

Nader, G. (2000). Rice straw utilization by cattle. *Report to the rice research board* December. http://www.syix.com/rrb/00rpt/StrawCattle.htm.

Muhammad, I.R., Mohammed, B., Mustapha, A., Ahmad, M.Y. and A bdurrahman, L.S. (2008). Use of legume in the improvement of Ensiling quality of Colombus Grass (*Sorghum almum* Pardi). Research Journal of Animal Science, 2(4): 109-112.

Narayan, D., Sharma, K. and Naulia, U. (2004). Nutritional evaluation of Lentil straw and urea treated wheat straw in goats and lactating buffaloes. *Asian-Australian Journal of Animal Science* 17(11):1529-1534.

Ngele,M.B., Adegbola, T.A., Bogoro, S.E.S., Abubakar, M. and Kalla, D.J.U. (2009). Rumen degradability and kinetic properties of urea and poultry litter treated rice straw. *Emirate Journal of Food and Agricultural* 21 (1): 32-39 http://cfa.uaeu.ac.ae/ejfa.shtml.

Ngere, L.O., Adu, I.F. and Mani, I. (1979). Report of sub-committee on small ruminants: Ad-hoc committee on national livestock breeding policy. National Animal Production Research Institute: Shika, Nigeria.

Nguyen, X.T. (1998).The need for improved utilisation of rice straw as feed for ruminants in Vietnam: An overview Livestock for Rural Develpoment vol. 10

Nguyen, X.T., Magne, M. and Cu, X.D. (2001). Effects of treatment of rice straw with lime and/or urea on its chemical composition, in-vitro gas production and in-sacco degradation characteristics. Livestock Research for Rural Development 13 (4).

Njidda, A.A. and Kibbon, A. (2004). Effects of graded levels of cane molasses on the performance of growing Balami sheep in the sub-Sahelian zone of Borno state, Nigeria. *Proceedings of the 9th Annual Conference of Animal Science Association of Nigeria* (ASAN). September 13th -16th, 2004. Ebonyi state university, Abakaliki, Nigeria, Pp 111-114.

Nisa, M., Sarwar. M. and. Khan, M.A. (2004). Influence of *ad libitum* feeding of urea treated wheat straw with or without corn steep liquor on intake, *in situ* digestion kinetics, nitrogen metabolism and nutrient digestion in *Nili-Ravi* buffalo bulls. *Australian Journal of Agricultural Research* 55:229-236.

Norton, B.W. (1994). Tree legume as dietary supplements for ruminants, In: R.C. Gutteridge and P.M. Shelton (eds.) forage tree legumes in tropical agriculture. CAB International, Wallingford. 202-215pp.

Norton, B.W. (2003). The nutritive values of tree legumes as supplement for ruminants In: Forage tree legumes in Tropical Agriculture. Editors Gutterridge, R.C. and Shelton, H.M.

Nour, A.M. (2003). Rice Straw and Rice Hulls in Feeding Ruminants in Egypt. Department of Animal Production, Faculty of Agriculture, Alexandria University, Alexandria, Egypt. Pp 68

Nurfeta, A., Tolera, A., Eik, L.O. and Sundstol, F. (2009). Feeding value of enset (*Ensete ventricosum), Desmodium intortum* hay and untreated or urea and calcium oxide treated wheat straw for sheep. *Journal of Animal Physiology and Animal Nutrition.* 93:94–104.

Nuru, S. (1985). Future trends of small ruminant production in Nigeria. *Proceedings on National conference in Small Ruminant Production* held in Zaria, Nigeria. 6th - 10th October 1985.

Nyako, H.D., Malgwi, I.H., Yahaya, M.M., Aminu, I.M., Abdullahi, S., Tukur, I.I., Mohammed, I.D. and Mohammed, A. (2015). Effect of different levels of farm yard manure, N.P.K. and Urea on the growth performance of *Brachiaria decumbens* grass. *Proceedings of 20thAnnual Conference Animal Science Association of Nigeria* 6 - 10th September, 2015, Ibadan. Pp. 712-716.

O'Donovan, P.B., Soomro. F.M., Wagennar. J.P., Rehman, S. and Bukhari, F.A., (1997). Urea treatment of straw- Friendly system improved upon in Balochistan. *Livestock Research for Rural Development* 9, 5.

Okah, U., Okeke, C.N. and Anya, M.I. (2012). Intake and digestibility of dietary maize processing waste by West African Dwarf sheep. *Journal of Agricultural Technology* 8(4): 1277-1284.

Okano, K., Ohkoshi, N., Nishiyama, A., Usagawa, T. and Kitagawa, M. (2009). Improving the nutritive value of madake bamboo, *Phyllostachys bambusoides*, for ruminants by culturing with the white-rot fungus *Ceriporiopsis subvermispora*. *Animal Feed Science Technology*, 152:278–285.

Olofin, E.A. (1987). Some aspects of the physical geography of the Northern region and Related Human Responses. BUK, Press

Omokanye, A.T., Onifade, O., Olorunju, P.E., Adamu, A.M., Tanko, R.J. and Balogun, R.O. (2001). The evaluation of dual-purpose groundnut (*Arachis hypogea*) varieties for fodder and seed production at Shika, Nigeria. *Journal of Agricultural Science Cambridge*, 136:75-97.

Oni, O.O. (2002). Breed and Genetic improvement of small Ruminants (sheep and goats). In: Lakpini, C.A.M., Adamu, A.M., Ehoche, O.W. and Gefu, J.O. (Eds). Manual for small ruminant production in Nigeria. Workshop at National Animal Production Research Institute. Ahmadu Bello University, Zaria, Shika, Nigeria. 13th – 18th Jan., Pp 1-7.

Onyeonagu, C.C. and Njoku, O.L. (2010). Crop residues and agro-industrial by-products used in traditional sheep and goat production in rural communities of Markudi LGA. *Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension*Volume 9 Number3 pp. 161 -169

Orskov, E.R. (1986). Strategies for Rural Development with Emphasis on Livestock production, Resource Utilization and FAOAssistance, In*:* D. A. Little A.N. Said (Eds). *Utilization of Agricultural By-Products as Livestock Feed in Africa. Proceedings of a Workshop Held at Ryalls Hotel, Balantyre, Malawi*, September, 1986, Pp 159-164.

Orskov, E.R. and Ryle, M. (1990). *Energy Nutrition in Ruminants*. Elsevier.

Osineye, O.M. (2015). Effects of varying dietary zinc levels on energy and nitrogen utilization in West African Dwarf kids. *Journal, Nigerian Society for Animal Production*, 42(1): 171-177.

Otchere, E.O., Dodzie, C.B.M., Erbynm, K.G. and Ayebo, D.A. (1977). Response of sheep to rice straw or cassava peels fortified with urea and molasses as supplement feeds to grazing. *Ghana Journal of Agriculture Science*, 10:61-66.

Owen, E., Klopfenstein, T. and Urio, N.A. (1984). Treatment with other chemicals. In: Sundstøl, F. and Owen, E.C. (Eds.) *Straw and Other By-products as Feed*. Elsevier. Amsterdam. Pp 248-275.

Owen, E. and Jayasuriya, M.C.N. (1989). Use of crop residues as animal feeds in developing countries. *Research Development Agriculture,* 3: 129-138.

Pagot, J. (1992). *Production and climate. In Animal Production in the tropics.* Macmillan CTA. London pp. 69-91.

Parnich, T. (1983). Urea-ensiled rice straw as a feed for cattle in Thailand. S*outh African Journal of Animal Science* 133.

Paulino, M.F., Detmann, E., Valente, E.E.L. (2008). Nutrição pastejo bovine em. In: *Symposium on strategic management da pastagem*, 4, 2008, Viçosa, MG. Anais Viçosa, MG: SIMFOR, 2008. Pp.131–169.

Peacock, C.P. (1983). A rapid appraisal of goat and sheep flock demography in East and West Africa. Working document No. 28. ILCA, Nairobi, Kenya.

Pearce, G.R., Lee, J.A., Simpson, R.J. and Doyle, P.T. (2014). Sources of variation in the nutritive value of wheat and rice straws School of Agriculture and Forestry, University of Melbourne, Parkville, Victoria 3052, Australia.

Perry, B.D., McDermott, J.J., Randolf, T.F., Sones, K.R. and Thornton, P.K. (2002). Investing in animal health research to alleviate poverty. *International Livestock Reseach Institute (ILRI), Nairobi, Kenya*. Pp. 138.

Perry, B.D., Randolf, T.F., McDermott, J.J., Sones, K.R. and Thornton, P.K. (2003). Investing in animal health research to alleviate poverty. ILRI, Nairobi, Kenya. Pp148.

Pirie, R. and Greenhalgh, J.F.D. (1978). Alkali treatment of straw for ruminants. I. Utilization of complete diets containing straw by beef cattle. *Animal Feed Science Technology,* 3:143–154.

Phang, O.C. and Vadiveloo, J. (1992). Effects of varieties, botanical fractions and supplements of palm oil by products on the feeding value of rice straw in goats. *Small Ruminant Res*earch, 6: 295-301.

Phengsavanh, P. (1997). *Environmental adaptation of forages in Lao PDR*. Livestock Development Division, DLF, MAF, Lao PDR.

Poungchompu, O., Wanapat, M., Wachirapakorn, C., Wanapat, S. and Cherdthong, A. (2009). Manipulation of ruminal fermentation and methane production by dietary saponins and tannins from mango stem peel and soapberry fruit. *Arch Animal Nutrition*. 63:389–400.

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

Prasad, R.D.D., Reddy, M.R., Reddy, G.V.N. (1998). Effect of feeding baled and stacked urea treated rice straw on the performance of crossbred cows. *Animal Feed Science Technology*. 73:347–352.

Preston, T.R. (1985). Strategies for Optimizing the Utilization of Crop Residues and Agro-Industrial Byproducts for Livestock Feeding in Tropics. Towards Optimal Feeding of Agricultural Byproducts to Livestock in Africa. *Proceedings of a Workshop Held at the University of Alexanderia. International Livestock Center for Africa (*ILCA), Egypt. Pp 17.

Preston, T.P., Leng, R.A. (1987). Manipulation of feeding and the rumen ecosystem. Anonymous. Matching ruminant production system with available resources in the Tropics and Sub-tropics. Penambul books, Armidale, Australia, pp. 83-92.

Preston, T.R. (1995). Tropical Animal Feeding- A Manual for Research worker. FAO *Animal production and Health*. Paper 126. Rome.

Promma, S., Tasaki, I., Cheva-Isarakul, B. and Indratula, T. (1994). Effect of feeding neutralized urea treated rice straw on milk production of crossbred Holstein cows. *Asian-Australian Journal of Animal Science*, 7: 493-498.

Punj, M.L., Sharma, K.O. and Bhatia, I.S. (1977). Action of Sodium hydroxide on wheat straw. *Indian Journal of Dairy Science* 30:160-161.

Puri, J.P. and Gupta, B.N. (2001). Effect of feeding rice straw treated with two levels of urea and moisture on growth and nutrient utilization in crossbred calves. *Indian Journal of Animal Nutrition*, 18: 54 – 59.

Raay, J.G.T. and De Leeuw, P.N. (1975). The importance of crop residues as fodder. A resource analysis in Katsina province Nigeria. *Samara Research Bulletin* No. 139 Samaru, Zaria, Nigeria Ahmadu Bello University.

Rai, S.N., Singh, M., Amrith Kumar, M.N., Walli, T.K., and Pradhan, P.K., (1993). Practical methods and other issues of urea-ammonia treatment of straw-a review. Feeding of ruminants on Fibrous crop residues Indo-Dutch project on Bioconversion of crop Residues Publishing Pp 306-319.

Rai, S.N and Agrawal, S.K. (1991). Effect of substitution of green fodder with ammoniated straw on nutrient utilization and milk production in Murrah buffaloes. *Buffalo Journal* 5:51-61.

Ranhotra, G.S. and Jordan, R.M. (1996). Protein and energy requirements of lambs weaned at 6-8 weeks of age as determined by growth and digestion studies. *Journal of Animal Science*, 25: 630-635.

Ranjhan, S.K. (1997). *Animal nutrition in the tropics.* 4th revised, edn. Vikas Publishing House PVT Ltd.pp. 557.

Rehrahie, M. (2001). Biological and Economical Evaluation of Urea Treated Teff and Barley Straw Based Diets to Crossbred Dairy Cows in the Highlands of Ethiopia Swedish University. Uppsala, Sweden. Msc Thesis. Pp. 1-12 (II).

RIM (1992). Nigerian Livestock Resources four volume report to the Federal Government of Nigeria by Resource Inventory and Management Limited. Urban reports and commercially managed livestock report.

Rivero, D.H., Soares, S.R., Filho, G.L., Godleski, J.J., Antonangelo, L., Dolhnikoff, M. and Saldiva, P.H. (2005). Acute cardiopulmonary alterations induced by fine particulate matter of São Paulo, Brazil. *Toxicology Science* 85(2): 898-905.

Rumirez-Orduna R., Ramirez R.G., Gonzalez-Rodriguez H. and Haenlein G.F.W. (2005). Mineral content of browse species from Baja California Sur, Mexico. *Small Ruminant Research***.** 57(1): 1-10.

Ruthenberg, H. (1980). Farming Systems in the Tropics. Clarendon Press Oxford, Britain Saadulah, M. M., Haque and. Dolberg, F. (1981). Treatment of rice straw with lime. *Tropical Animal Production,* 6:116-120.

Saadullah, M., Haque, M. and Dolberg, F. (1980). Treating rice straw with animal urine. *Tropical Animal Production 5:3.*

Saadullah, M., Haque, M., and Dolberg, F., (1981c). Effectiveness of ammonification through urea in improving the feeding value of rice straw in ruminants. *Tropical animal production* 6, 30-36.

Saadullah, M, Haque, M. and Dolberg, F. 1982). Treated and untreated rice straw to growing cattle. *Tropical Animal Production*, 7: 187–190.

Sano, H., Shibasaki, S. and Sawada, H. (2009). The effect of the source of nitrogen supplementation on nitrogen balance, rates of plasma leucine turnover, protein synthesis and degradation in sheep. *Arch Animal Nutrition* 63:401–412.

Sarnklong, C., Cone, J.W., Pellikaan, W. and Hendricks, W.H. (2010). Utilization of rice straw and different treatment to improve its feed value for ruminants: A review. *Asian-Australian Journal Animal Science.* 23(5): 680-692 www. Ajas. Info

Sarwar, M., Khan, M.A. and Zafar, I. (2002). Feed resources for livestock in Pakistan. *International Journal of Agricultural Biology* 1:186-194.

Sarwar, M., Khan, M.A. and Nisa, M. (2004). Effect of organic acids or fermentable carbohydrates on digestibility and nitrogen utilization of urea-treated wheat straw in buffalo bulls. *Australian Journal of Agricultural Research,* 55:223-228.

SAS. (2001). Procedure Guide version 9.1. Statistical Analysis Systems Institute, Cary, NC.

Satter, L.D. and Syter, L.L. (1974). Effects of ammonia concentration on rumen microbial protein production *in vitro*. *The British Journal of Nutrition*. 32:199 – 208.

Scherf, B. D. (2000). World watch list for domestic animal diversity. 3rd Edition.

Schiere, J.B., Nell, A.J. and Ibrahim, M.N.M. (1988). Feeding of urea-ammonium treated rice straw. *World Animal Review,* 65: 31-42.

Schiere, J.B. and Ibrahim, M.N.M. (1989). Feeding of urea-ammonia treated rice straw. Pudoc Wageningen. Netherlands.

Schiere, J.B., Ibrahim, M.N.M., Sewalt, V.J.H. and Zemmelink, G. (1989). Response of growing cattle given urea-treated and untreated rice straw to supplementation with rice bran and lick blocks containing urea and molasses. *Animal Feed Science and Technology*. 26: 179-189.

Schultze-Kraft, R. (1992). *Andropogon gayanus* Kunth. In: 't Mannetje, L. and Jones, R.M. (eds) *Plant Resources of South-East Asia No. 4. Forages*. (Pudoc Scientific Publishers, Wageningen, the Netherlands). pp. 44-46.

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

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

Sharma, R.P., Pandey, A.K. and Singh, R.S. (2012). Aggressive Action to reduce carbon dioxide emissions: Burning practice of paddy straw now sequestering carbon. Noto-are 16424734: Agriculture http://www.notoare.com/16424734.

Shen, H.S., Ni, D.B. and Sundstol, F. (1998). Studies on untreated and urea treated rice straw from three cultivation season: I Physical and chemical measurements in straw and straw fractions. *Animal Feed Science Technology,* 73: 243-261.

Shen, H.S., Sundstøl, F., Eng, E.R. and Eik, L.O. (1999). Studies on untreated and urea-treated rice straw from three cultivation seasons: 3. Histological investigations by light and scanning electron microscopy. *Animal Feed Science Technology*, 80:151–159.

Sinha, D., Praskash, B., Neog, B.N., Baruah, K.K., Sarmah, S. and Rajkhowa, C. (2011). Intake, digestibility and nitrogen balance in Mithun (*Bos frontalis*) offered urea treated paddy straw based feed blocks. *Tropical Animal Health Production.* 43:383–387.

Singh, S.P. and Gupta, B.N. (1986). Effect of feeding ammoniated straw impregnated with urea on digestibility and volatile fatty acid production rates in buffaloes. *Indian Journal of Animal Science*, 56: 1210-1214.

Singh, S., Kundu, S.S., Negi, A.S. and Pachouri, V.C. (2010). Performance of growing kids on rations with Lablab *(Lablab purpureus*) grains as protein source. Livestock Research for Rural Development. 22 (93). Retrieved December 28, 2010, from http://www.Irrd.org/Irrd22/5/sing22093.htm.

Smith, L.W., Calvert, C.C. and Cross, H.R. (1979). Dehydrated poultry excreta *vs* cottonseed meal as a nitrogen supplements for Holstein steers. *Journal of Animal Science* 48:633.

Smith, O.B. (1991). Small ruminant feeding systems for small- scale farmers in humid West Africa. A paper presented at joint feed resources networks workshop held in Gaborone, Botswana 4-8 March *http://www.fao.org/wairdocs/ilri/x5519b/x5519b1f.htm*

Smith, T.L., Merry, S.T., Harris, D.L., Ford, J.J., Ike, J., Archibong, A.E. and Ramesh, A. (2007). Species specific testicular and hepatic microsomal metabolism of benzopyrene, an ubiquitous toxicant and endocrine disruptor. *Toxicology. In vitro,* 21: 753-758.

Solomon, B, (2004). Assessment of Livestock Production Systems Feed Resource base in Sinana Dinsho district of bale highlands, Southeast Oromya, MSc. Thesis, Alemaya University, Dire Dawa, Ethiopia.

Stanforth, A.R. (1979). Cereal straw. Closendo Press, Great Britain.

Sun, Q.H. (1985). Alkali treated wheat straw for beef cattle. *Feed Research*, 5:15-16.

Sundstol, F.E., Coxworth, E. and Mowat, D.N. (1978). Improving the nutritive value of straw and other low quality roughages for treatment with ammonia. *World animal Review* 26:13-21.

Sundstol, F. (1984). Recent advances in development and utilisation of chemically treated low quality roughages. *Proceedings of an International Workshop held in Khon Kaen, Thailand* on 29 November - 2 December , 1984. pp 121-146.

Sundstol, F. and Coxworth, E.M. (1984). Ammonia treatment. In: Sundstol, F. and Owen, E.(eds). Straw and other fibrous by-products as feed. *Elsevier, Amesterdam*, pp 196-247.

Sundstol, F. and Owen, E. (1984). Straw and other fibrous by-products as feed. Elsevier Amsterdam.

Swan, H. and Clarke, V.J. (1974). The use of processed straw in rations for ruminants. *Proceedings University of Nottingham Nutriton Conference of Feed Manufacturers,* 8:205– 233.

Tagel-Din, A.E., Nour, A.A., Nour, A.M., Abou-Akkada, A.R. (1989). Evaluation of diets containing different levels of rice or berseem straws and concentrates fed to sheep. *Indian Journal of Animal Science* 59, p. 465–469.

Tanko, R.J., Kallah, M.S. and Otchere, E.O. (1990). Livestock production in Northern Nigeria, dry matter yield and chemical composition of dual-purpose legumes. Paper presented at the *15th Annual Conference of the Nigerian Society for Animal Production* held at the Ogun State University Ago-Iwoye, Nigeria, 25-29 March.

Tanko, R.J. (1993). Productivity of rangeland sites in the northern Guinea Savanna of Nigeria. MSc. Thesis Faculty of Agriculture, Ahmadu Bello University, Zaria. 73 pp.

Tannins, R.J. and Maylor, A.W. (1968). Physical and chemical studies of a low molecular weight form of cheese. *Biochemical Journal,* 108:771.

Tchinda, B., Wega, D. and Njwe, R.M. (1993). Rumen degradation of elephant grass supplemented with graded levels of perennial peanut by West African Dwarf sheep. In: Lebbie S.H.B., B., Rey and E.K., Irungu (Eds). Small ruminant's research and Development in Africa *Proceedings of the Second Biennial Conference of the African Small Ruminant Research Network*, AICC, Amsha, Tanzania. 7-11th December, 1992. ILCA (International Livestock Centre for Africa/ CTA (Technical Centre for Agriculture and Rural Co-operation) ICCA, Addis Ababa, Ethiopia, pp: 187-190.

Tegbe, T.S.B., Iyeghe, G. and Otchere, E.O. (1995). Non-conventional feedstuffs for swine: NAPRI's Experience in NAERLS National Pig Production Workshop.

Tesfaye, A. (1999). The Role of Crop Residues as Livestock Feed Resources in Semi arid Areas of Adamitulu District, Ethiopia. An MSc Thesis Presented to the University of Nairobi, Kenya. p 90.

Teshome D.A. (2009). On-farm Evaluation of Urea Treated Rice Straw and Rice Bran Supplementation on Feed Intake, Milk Yield and Composition of Fogera Cows, North Western Ethiopia. An Msc. Thesis Submitted to the Department of animal science and technology school ofgraduate studies. Bahir Dar University. Pp. 94.

Theander, O. and Aman, P. (1984). Anatomical and chemical characteristics. In: Straw and Other Fibrous By-products as Feed. Developments in *Animal Veterinary Sciences,* 14. Elsevier, Amsterdam, pp. 45-78.

Tibbo, M. (2006). Productivity and Health of Indigenous sheep breeds and crossbreds in the Mokara man sheep. *Journal of Applied Animal Research* 25:97-100.

Tolkamp, B. (1988). Feed intake regulation and small ruminants: Goat production in the tropics (Eds) O.B. Smith and H.G. Bosman) Pudoc. Wageningen. Pp 67-75.

Trach, N.X., Mo, M. and Dan, C.X. (2001). Effect of treatment of rice straw with lime and / or urea on its intake, digestibility and rumen liquor characteristics in cattle. *Journal of Livestock for Research Rural Development,* Vol. 13 No. 5.

Uboh, F.E., Akpanabiatu, M.I., M.U. Eteng, M.U. and Eyong, E.U. (2010). Exposure to gasoline and kerosene evapours: A risk factor for nephrotoxicity in rats. *Internet Journal of Toxicology* 7: 2. (Inpress).

USDA (2010). Producer, supply and Distribution online Database.Washington, D.C. United states Department of Agriculture.

Vadiveloo, J. and Fadel, J.G. (1992). Compositional analyses and rumen degradability of selected tropical feeds. *Animal Feed Science Technology* 37, 265±279.

Vadiveloo, J. (1995). Factors contributing to varietal differences in the nutritive value of rice straw. *Animal Feed Science Technology* 54, 45±53.

Vadiveloo, J. (2000). Nutritional properties of the leaf and stem of rice straw. *Animal Feed Science Technology* 83:57-65.

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

Van Soest, P.J. and Jones, L.H. (1968). Effect of silica in forages upon digestibility *Journal of Dairy Science* 51, 1644-1648.

Van Soest, P.J. (1988). Effect of environment and quality of fibre on the nutritive value of crop residues. In: Eds. J.D. Reeds, B.S. Copper and P.J.H. Neate. Plant breeding and the nutritive value of crop residues. *Proceedings of an International workshop international livestock centre for Africa,* Addis Ababa, Ethiopia, 7-10 December, 187

Van Soest, P.J., Robertson, J.B., and Lewis, B.A. (1991). Methods for dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science, 74*(10), 3583–3597.

Van Soet , P.J. (1994). Nutritional ecology of the ruminants. In P.J. Van Soet *Fiber and physiochemical properties of feeds* (2nd ed.). Ithaca and London: Cornell University Press,. pp. 140–155.

Van Soest, P.J. (2006). Review: rice straw, the role of silica and treatments to improve quality *Animal Feed Science Technology* 130:137-171.

Van Soest, P.J. (2006). Animal Feed Science and Technology (Impact Factor: 1.61). 01/2006; 30(130):137-171. DOI: 10.1016/ *Journal ofAnimal Feed Science* 2006.01.023.

Veras, M.M., Damaceno-Rodrigues, N.R., Silva, R.M., Julia Scoriza, J.N., Saldiva, P.H., Caldini, E.G. and Dolhnikoff, M. (2009). Chronic exposure to fine particulate matter emitted by traffic affects reproductive and fetal outcomes in mice. *Environmental Research,* 109(5): 536-543.

Verma, D.N., Lal, S.N., Asrey, R., Prakash, O., and Singh, S.P., (1996). Crop residues from rice farming for small-scale livestock production. *Animal Science,* 11: 385-394.

Villas-Bôas SG, Esposito E, Mitchell, D.A. (2002). Microbial conversion of lignocellulosic residues for the production of animal feeds. *Animal Feed Science Technology*. 98:1–12.

Wahed, R.A. and Owen, E. (1986). Comparison of sheep and goats under stall-feeding conditions: Roughage intake and selection. *Animal Production* ,42:89-95.

Walli, T.K., Rao, A.S., Singh, M., Rangnekar, D.V., Pradhan, P.D., Singh, R.B., and Ibrahim, M.N.M. (1995). Urea treatment of straw. *Handbook for straw feeding systems.*

Wanapat, M., Sundstøl, F. and Garmo, T.H. (1985). A comparison of alkali treatment methods to improve the nutritive value of straw. I. Digestibility and metabolizability. *Animal Feed Science Technology*. 12:295–309.

Wanapat, M. and Kongpiroon, N. (1988). Intake and digestibility by native cattle of straw and stubble of glutinous and nonglutinous varieties of rice. In: Dixon, R.M. (ed.), *Proceedings of a Workshop on Ruminant Feeding Systems Using Fibrous Agricultural Residues*. International Development Program of Australian Universities and Colleges (IDP), Canberra, Pp. 133-135.

Wanapat, M., Cherdthong, A., Pakdee, P. and Wanapat, S. (2008). Manipulation of rumen ecology by dietary lemon grass (*Cymbopogon citrates Stapf*.) powder supplementation. *Journal of Animal Science.* 86:3497–3503.

Wanapat, M., Polyorach, S., Boonnop, K., Mapato, C. and Cherdthong, A. (2009). Effect of treating rice straw with urea or urea and calcium hydroxide upon intake, digestibility, rumen fermentation and milk yield of dairy cows. *Livestock Science,* 125:238-243.

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

Wang, J. and Christopher, S.A. (2003). Inter-comparison between satellite-derived aerosol optical thickness and PM2.5 mass: Implications for air quality studies. *Geophysics Research. Letter*, 30:2095 2098.

Warner, A.C.J. (1964). Production of volatile fatty acids in the rumen. Methods of measurements *Nutrition Abstract Review*, 34 (1964), pp. 339–345.

Weaver, S. (2005). *Sheep: Small-Scale Sheep Keeping for Pleasure and Profit*. 3 Burroughs Irvine, CA 92618: Hobby Farm Press, an imprint of Bow Tie Press, a division of Bow Tie Inc. ISBN 1- 931993- 49-1.

Werner, W.H., Rey, H.G. and Weieliger, H. (1976). Method of plasma glucose determination. *Journal of Analytical Chemistry*, 252:224-228.

Weston, R.H. (1985). The regulation of feed intake in herbage-fed ruminants. *Proceedings of the Nutrition Society of Australia* 10:55-62.

Whittier, D.W., Zajac, A. and Umberger, S.H. (2003). Control of Internal Parasites in Sheep. Virginia Cooperative Extension Publication Number 410–027, October 2003 http://www.ext.vt.edu/pubs/sheep/410-027/410-027.html Accessed Jan.27.Retrieved 12/11/2015.

Wilkins, R.J. (1998). The preservation of forage. World Animal Science B Disciplinary approach (Orskov, ER ed) Elsevier Scientific Publisher, Amterdam, The Netherlands 305-339. NRC, 1996 in Madwel journal. *Journal of Animal and Veterinary Advances Year:* Volum**e:** 9(18):2396-2400 DOI: 10.3923 / javaa. 2010. 2396. 2400.

Wilkins, R.J. (2000). Forages and their Role in Animal Systems. In: D. I. Givens, E. Owen, R. F. E. Axford and H.M. Omed (eds) *Forage Evaluation in Ruminant Nutrition*. CAB Publishing. Wallingford, UK. Pp. 1-14.

Williams, T.O., Hiernnaux, P., Fernandez, Rivera, S. and Turner, M. (2001). Livestock production and sustainable Agricultural Development in Semi Arid West Africa. Paper presented at the Regional workshop on technology options and transfer systems for food grain production in sub-saharan Africa, held at Abidjan. April, 26-29.

Williamson, G. and Payne, W.J.A. (1978). *An introduction to animal husbandry in the tropics* (3rd edition). ELBS series. Longman, London Pp463-484.

Wilson, J.R. (1993). Organization of forage plant tissues. In: Jung, H.G., Buxton, D.R., Hatfield, R.D., Ralph, J. (Eds), Forage cell wall structure and digestibility. Madison, W.I. USA 1-32.

Wongsrikeao and Wanapat (1985). The effects of urea treatment of rice straw on feed intake and live weight gain of buffaloes. *In:* The Utilization of Fibrous Agricultural Residues as Animal Feeds. Doyle. P.T. (Ed.) pp 81-84 IDP Canberra.

Xing, T.X. (1995). *Nutritional value and utilization of crop residues*. Changsha, China: Hunan Science and Technology Press. Pp 69

Xiong, Y.Q. (1986). Processing and treatment of crop residues and the utilization of treated residues in ruminant feeding. *Chinese Journal of Animal Science*, 22(2):21-23.

Yadav, B.P.S. and Yadav, I.S. (1988). Nitrogenous constituents in rumen metabolites and blood serum of adult cattle fed urea treated straws. *Indian Journal of Animal Science.* 58: 107.

Yakubu, A., Raji, A.O. and Omeje, J.N. (2010). Genetic and phenotypic differentiation of qualitative traits in Nigerian indigenous goat and sheep populations. *Journal of Agriculture and Biological Science*, 5:58-66.

Ye, R.S., Hong, R.L., and Zhu, Y.H. (1999). Report on use of alkali-treated rice straw in dairy cow diets. *China Dairy Cattle*, 2:28-29.

Yenikoye, A., Mariana, J.C. and Celeux, G. (1989). Follicular growth during the oestrus cycle in Peul (Uda) sheep. *Animal Reproduction Science.* 21: 201-211.

Yu. H., Guo, G., Zhang, X., Yan, K. and Xu, C. (2009). The effect of biological pretreatment withthe selective white-rot fungus *Echinodontium taxodii* on enzymatic hydrolysis of softwoods and hardwoods. *Bioresource Technology,* 100:5170–5175.

Zaman, M.S., Owen, E. and Pike, D.J. (1994). The calculation method used for urea, moisture, treatment time and temperature on *in-vitro* digestibility. *Animal Feed Science and Technology*. 45: 271-282.

Zaman, M.S. and Owen, F. (1995). The effect of calcium hydroxide and urea treatment of barley straw on chemical composition and digestibility *in-vitro*. *Animal Feed Science and Technology.* Volume 51: 165-171.

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

Zan, B.M. (1989). *Influence du niveau d'offre sur la digestibilité* in vivo *de la paille de sorgho et de fanes de niébé chez les ovins*. Mémoire de fin d'étudesd'ingénieur du développement rural, option élevage,Université de Ouagadougou, Burkina Faso, 5

Zemmenlink, G. (1999). Utilization of poor quality roughages in Northern Guinea savanna Zone. A paper presented at the proceeding of the International symposium on Animal production in the topics held at University of Ibadan 26th –29th March 1973. Edited by J.K. Loosli, V.A. Oyenuga and G.M. Babatunde (1999), Printed by Heinaman Educational Book Nigeria PLc. Ibadan Nigeria,

APPENDIX

Cost of experimental feed materials used in the study

Cost of gamba hay----------₦5/kg

₦5 × 100 kg----------₦500

Cost of urea treated rice straw----------₦15/kg

₦15 × 100 kg----------₦1500

Cost of concentrate ingredients

Maize----------₦45/kg

45 × 100 kg----------₦4500

Wheat bran----------₦40/kg

40 × 100 kg----------₦4000

Cotton seed cake----------₦70/kg

₦70 × 100 kg----------₦7000

Rice milling waste---------==----------₦10/kg

Bone meal----------₦15/kg

Salt----------₦5/kg

Cost of live rams/ kg----------₦450.00

Cost of roughage consumed= cost of roughage × intake of roughage

Cost of concentrate consumed= cost of concentrate × intake of concentrate

Cost of total feed consumed = cost of roughage consumed + cost of concentrate consumed

Cost per kg live weight gain= $\frac{\text{cost of total feed consumed}}{\text{Weight gain}}$