STUDIES ON THE UTILISATION OF UREA-AMMONIATED STRAW AND UREA-MOLASSES BLOCK SUPPLEMENT AS DRY SEASON FEEDSTUFFS BY SHEEP IN GHANA

BY

ISAAC KOFI EGYIR

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GHANA

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DECLARATION

I hereby declare that, except for references which have been fully acknowledged, this thesis is the result of my original research work and contains no material which has been accepted as part of the requirements for any degree in any University or any material previously published or written.

....
Isaac Kofi Egyir
(Student)

....
Rev. Dr. K. Amaning-Kwarteng
(Supervisor)

....
Dr. J. E. Fleischer
(Co-Supervisor)

....
Prof. F. K. Fianu
(Co-Supervisor)

DEDICATION

This thesis is dedicated to my Dad and Mum,

for their love and care and

also to my beloved friend Miss. Irene S. Obeng

for prayer support and company at all times.

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ABSTRACT

Three experiments were undertaken to evaluate the nutritive value of urea-ammoniated rice straw and urea-molasses block supplement for dry season feeding to sheep.

Experiment One compared the feeding value of untreated straw (US), ammoniated straw (AS) and urea-molasses block supplemented straw (UMBS). Three fistulated and three "intact" sheep were assigned to a two 3 x 3 Latin Square designed. Parameters investigated include dry matter intake, lightweight changes and nutrient digestibilities.

The difference between the dry matter intake of AS (768.58g/d) and UMBS (707.24g/d) was significant ($P<0.05$) and both were superior to US (555.29g/d). Both intake and apparent digestibility of crude protein were higher ($P<0.05$) for AS (48.55 and 73.88) than UMBS (27.55 and 67.01). Similarly, cellulose digestibility was higher in AS (68.4) than UMBS (60.03). However, the two diets did not differ in intake or digestibility of other nutrients. Average daily gari (ADG) were 10.70g/d, 72.0g/d and 68.92g/d for US, AS and UMBS respectively. The difference were not significant ($P>0.05$) between AS and UMBS. Both were however, significantly ($P<0.05$) different from US.

In situ studies in Experiment Two indicated that the extent and rate of DM and NDF degradation were higher with UMBS than AS and US. The values for crude protein were however highest with AS followed by UMBS.

Gari and kokonte were used in place of wheat flour as slow degrading dietary energy source in the urea-molasses block in Experiment Three. The crude fibre content of the blocks were 340g/kg, 270g/kg and 300g/kg for Gari contained block (GB) kokonte contained block (KB) and Wheat Flour contained block (WB) respectively. The higher fibre content of GB promoted very high intake of both block and straw. The intakes were 0.81 and 0.78 kg/d for GB, 0.50 and 0.47 kg/d for KB and 0.47 and 0.54 kg/d for WB. GB accordingly recorded the best feed conversion efficiency which resulted in the highest growth rate of the sheep.

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CHAPTER ONE

INTRODUCTION

Feeding Ghana's ruminant population is a major problem especially with the urban dwellers engaged in livestock production. The main requirement of ruminant feed in the country is mostly met by natural pastures whose quality and quantity fluctuate with the season. Some liveweight gains are achieved in the wet season followed by considerable losses during the dry season. The production of cereal crops to meet the ever increasing demand for food has led to increase in production of crop residues which abound in the country. According to Fleischer (unpublished) about six million metric tonnes of crop residues are produced yearly in the country now.

The crop residues are generally of low nutritive value, the majority of which is either burnt or used as fuel in the home. Rice straw for instance, even though contains about 80% potentially digestible substances (Jackson, 1978) has a digestibility by ruminants of only 45-50%. Furthermore the amount the animals can eat is limited to less than 2% of body weight because of the slow rate at which it is fermented in the rumen (Jackson, 1978). It has, however, been reported that mature draught animals appear to maintain a low body condition and work satisfactorily on the straw diet alone (Preston and Leng, 1987). For most production purposes therefore, the straw must either be supplemented with dietary concentrate or be upgraded through chemical treatments before used as feed (Amaning-Kwarteng, 1991).

A variety of chemical treatments have been tested for their potential to enhance digestibility of crop residues. These treatments usually improve digestibility by breaking the bonds between lignin and cellulose and hemicellulose thus increasing the extent and rate of digestion. One of the most acclaimed chemicals for crop residue treatment is urea. Research has proved ammoniation by urea to be effective in improving the *in vitro* organic matter digestibility (Quashie, 1993), Voluntary intake and *in vitro* DM digestibility of wheat straw (Cloete, De Villiers and Kritzinger, 1983).

Supplemental cereal grains have been fed to alleviate energy deficiency associated with straw diets. However, some researchers have reported a decline in straw intake and digestibility with the supplementation (Horn and McCollum, 1987). Several theories have been proposed to explain the intake and digestibility depressing effects of readily fermentable carbohydrates such as the grains. These include competition between cellulolytic and non-cellulolytic bacteria ruminal ammonia-nitrogen (El-Shazly ,Dehority and Johnson, 1961), pH shift (Mould, Orskov and Mann, 1983) and the use of alternative energy-sources by cellulolytic bacteria (Van Glyswyki and Schwartz, 1984). Nevertheless, addition of starch to non-protein nitrogen (NPN) supplemented straws is believed to help prevent ammonia toxicity by improving nitrogen metabolism in the rumen (Horn and McCollum, 1987). The use of a mixture of NPN and molasses to offset the negative substitution effect and improve nitrogen metabolism has proved more successful (Munthali, Jayasuriya and Bhattachrya, 1991). Schlink (1980) as cited by Amaning-Kwarteng (1986) has also proved that molasses supplement is superior to grain supplementation.

Since the addition of NPN to energy supplemented straw diet has proved beneficial in situation where rumen degradable N is limiting, and the fact that molasses has shown better results than some other energy supplements which are not highly degradable in the rumen, a mixture of urea (NPN) and molasses could provide a better solution to the nutritive constraints associated with straw diets.

While every little *in vivo* studies have been done in Ghana to elucidate the effect of ammoniated straw on the performance of sheep, not much work has also been documented with the use of urea - molasses mixture.

This study was therefore conducted to examine the influence of urea ammoniation and urea molasses block supplementation on the performance of sheep fed rice straw applying *in vivo* and *in situ* techniques.

CHAPTER TWO

LITERATURE REVIEW

2.1 NATURE AND QUALITY OF AVAILABLE FEED RESOURCES

Table 2.1 shows the list of some of the major crop residues produced in Ghana. However, for purposes of this work more emphasis is placed on straws.

Table 2.1: Major crop residues and agro-industrial by-products produced in Ghana

Crop	Residue	By-products
Rice	Straw	Bran, Husk
Maize	Stover, cob	Bran, Husk
Sorghum	Stover, straw	Bran
Groundnut	Haulms, Husks	Groundnut cake
Cocoa	Pods	Shells
Sugarcane	Tops	Molasses, Bagasse
Coconut	Husks	Copra cake
Cassava	Peels and Rejects, Tops (leaves)	Starch
Cotton		Cotton Seed cake
Oil Palm		Palm kernel cake
Wheat (Imported)		Bran

2.1.1 Straws as Feedstuff

Straws are generally of low nutritive value to ruminants livestock because of high fibre and low nitrogen content and consequently low degradability in the rumen (Tables 2.2 and 2.3). With some treatment, (chemical, physical or biological) the nutritive value of the residue can be improved (Smith, 1987). Supplementation with energy together with protein sources without treatment has also been found to improve the nutritive value of straws (Dixon and Egan, 1987).

This chapter reviews the use of straws as feed and the scope for processing the straws and supplementation to enhance nutritive value.

Table 2.2: Proximate composition of major crop residues

Crop Residue	% Moisture	% DM				
		Crude Protein	Organic matter	Crude Fibre	Ether Extract	NFE
Maize stover	10	2-8	85-91	28-46	1-2	35-53
Sorghum stover	10	3-6	96	31-35	1-2	50-56
Rice Straw	10	2-9	75-90	20-45	1-4	29-48
Groundnut haulms	10-12	11-17	87-90	21-29	1-2.5	51-57
Cowpea tops	10-12	6-18	82-90	25-30	1.1.5	48-50
Sweet Potato tops	70-80	17-27	89-94	8-26	3-8	35-60
Sugar cane tops	90	20-22	82-83	15	3-3.5	42-46
Cocoa pods	75	2-9	86-91	21-32	2-3	61
Oil Palm (Tops)	56	2-9	75-90	20-45	1-4	33-56

Source: Smith (1987).

Table 2.3: Detergent fibre content and in *situ* degradability of major crop residues

Crop Residue	% DM								% DM losses (24h)
	NDF	Cell Content	ADF	Lignin	Cellulose	Hemi-Cellulose	Silica	T ½ (Hr)	
Maize Stover	70-80	-	-	7-9	43	24	5	70	30-80
Sorghum Stover	75-85	26	-	8-11	31	30	5	130	25
Rice Straw	60-80	20	45-55	4-10	24-52	5-45	12-17	60-80	30-34
Groundnut haulms	42-45	-	39-40	7-9	32	7	-	38	36
Cowpea vires	75	-	-	5-6	-	-	-	-	-
Cassava tops	30-45	20	-	-	-	-	-	30-50	45
Sugarcane tops	65-75	-	43	5-6	-	-	-	50-128	10

Source: Smith (1987)

2.1.2 Some Species of Straw in Ghana

Rice straws. Rice or paddy straw is produced in large quantities in many countries. According to Jackson (1978) rice straw is one of the largest unused feed resources in West Africa. The straw is unique among crop residues in that the stems are more digestible than the leaves (Jackson, 1978) in contrast to what is obtained in other straws (Coxworth, Kernan, Knipfel, Thorlacius and Crowle, 1981). Furthermore rice straws contain much silica (12-16%) and less lignin (6-7%) than other straws (Jackson, 1978). For these reasons paddy straw could be cut as close to the ground as possible if it is to be fed to livestock. The feeding value of rice straw could be upgraded to be equivalent to a medium quality hay by appropriate processing (Jayasuriya, 1979).

Forage Straws: The production of forage seed results in large quantities of grass and legume straws. As the production of forage is often from perennial stands it is usually desirable to remove the straw to help control diseases and insects to avoid smothering the next crop.

Anderson and Anderson (1980) reviewing possible uses of forage straw stated that the digestibility of all constituents of forage straws are low; their unpalatability and low nutrient density further reduced their value as livestock feed. Consequently, chemical and/or physical processing are necessary before forage straw can be used in growing rations for livestock.

Maize Stover: Many workers have shown that, it is desirable to harvest maize stover soon after grain harvest to avoid loses of nutrients in the field. Berger, Peterson, Klopfenstein and Brilton, (1979) compared beef steers fed with ensiled maize straw taken after high moisture grain was harvested or above one month later after dry grain was harvested with steers fed with normal maize silage. Average daily weight gain of the steers over two trials in different years were 0.85kg for early harvested stover, 0.48kg for late harvested stover and 0.88 for normal maize silage.

Other straws and by-products: The organic matter digestibility of cotton stalk as determined with cattle was only 32% compared with 40-47% for most straws (Levey, Holzer and Folman, 1980). Ammoniation was found to increase the digestibility considerably (Levey *et al.*, 1980).

Devendra (1981) reviewed non-conventional feed resources. Among feeds identified as having a high potential are cassava leaves which contained about 20% crude protein. Two problems, however, limit their use. One is high level of cyanogenic glycosides in some strains. The other is that the crude protein digestibility is often low and is attributable to the presence of tannins which bind the protein or affect enzyme activity (Reed, McDowel, Van Soest and Horvath, 1982).

The feeding value of by-products of the sugar industry have been studied recently by Nickerk in 1981. The cane tops which are discarded at harvest have Total Digestible Nutrients (TDN) content of about 50% (ie, ME value equivalent) and crude protein content of about 5% and can be used fresh or after ensiling. Bagasse, the fibrous residue remaining after sugar juice extraction is variable in composition. It has very little protein and its TDN content ranges from 26 to 46%. It has been identified that different processing methods affect the nutritive value of bagasse differently (Nickerk, 1981).

The potential of sorghum straw as animal feed has been demonstrated by Alhassan, Enoche, Adu, Obilana and Kallah (1984). However, differences in results existed between their values and those of other workers. These differences have been associated with animal species differences (Rees and Little, 1980; Amaning-Kwarteng, Kellaway, Spragg and Kirby, 1986).

2.1.3 Constraints to the Optimum Utilization of Crop Residues in Ghana

When fed unprocessed to livestock, crop residues are poorly consumed and ultimately result in slow animal response.

Bulkiness of the crop residues and difficulty in transportation constrain the utilization of crop residue especially when the residues have to be transported from areas with low animal population density to areas where animals are reared.

Bailing crop residues could reduce their bulkiness and hence increase the quantity that can be transported. However, the practice is too expensive for individual small holder farmers because of the equipment required and the need to bale large quantities to achieve economies of scale. Chemical treatments while very successful, present several practical problems for small holder agriculture.

As a remedy, farmers in high animal density populated areas should be educated on the means of improving the feeding value of these crop residues. The farmers should also be encouraged to form co-operatives so as to minimise cost in the processes by pulling together resources.

2.2 STRAWS IN RUMINANT NUTRITION

2.2.1 Introduction

The main feed resource for ruminant in Ghana is the natural grassland. Rose-Innes and Mabey (1964), Fianu, Atta-Krah and Koram (1972) and Amaning-Kwarteng (1991) have indicated that crude protein content of Ghanaian grass, in general, ranges from 50 to 130g/kg of DM in the rainy season but drops to 20-40g/kg DM in the four to six-month dry season. Consequently, animal performance fluctuates widely and there is overwhelming evidence of malnutrition in the animals during the dry season.

In the face of this feed resource inadequacy the use of crop residues in feeding ruminant livestock can be a good alternative. However, little use has been made of straws even though they are in abundance in many areas. This has been due to lack of knowledge on its potential nutritive value on the parts of the farmers.

2.2.2 Factors Affecting Intake and Utilization of Straw

Composition and utilization: It is possible that the components DM rather than DM digestibility may determine intake of low quality roughage. Blaxter and Wilson (1963) suggested 85g/kg DM as the minimum level of crude protein at which the activity of cellulolytic microbes in the rumen might be limited by the availability of nitrogen. Intake of low quality roughage has also been found to be inversely related to the cell wall content of the material (Goering and Van Soest, 1970).

Nutrient Imbalances: There is widespread evidence that imbalance of nutrients such as nitrogen and other mineral and vitamins depresses feed intake and animal performance. Liveweight losses resulting from feeding of all low quality roughage diets parallel those of low protein dry season grazing (Larsen and Amaning-Kwarteng, 1976). Anderson (1978) identified crude protein and phosphorus as the major deficiencies in straws; calcium levels are marginal and Zn deficiency could arise when straw is fed for extended periods. To achieve maximum intake of straw, a crude protein of 66-85g/kg DM has been found necessary (Blaxter and Wilson, 1963).

Straw: Concentrate ratio: The overall effect of supplementing straw diets with moderate levels of concentrate is to increase not only straw intake (where rumen degradable nitrogen is limiting) but also total DM and OM intakes. Church and Santos (1981) observed that with small amounts of protein concentrate such as soya bean meal, intake of both straw DM and energy significantly increased by almost 43%. Consumption of Straw DM improves with increased intake of concentrate till the concentrate level is over 20% of the total DM intake (Crabtree and Williams, 1971).

2.2.3 Establishment of an Efficient Rumen Environment

2.2.3.1 Microbial Consideration

The fermentative digestion of fibre in the rumen is carried out by a mixture of bacteria (Mackie and White, 1990), protozoa (Demeyer, 1981) and fungi (Akin and Borneman, 1990). Rumen microbes require a source of fermentable nitrogen, usually ammonia although some species require preformed amino acids and peptide (Russell and Baldwin, 1978). The low nitrogen content of most straws (Table 2.2) points to a need to combine them with feeds with high nitrogen content. The ideal NH_3-N concentration rumen for efficient digestion has been variously estimated at 50-70mg/litre (Satter and Slyter, 1974), 150-200mg/litre (Krebs and Leng, 1984) and at 230mg/litre (Merez, Orskov and McDonald, 1977). These levels are not easy to maintain in stall fed animals over a 24-hour period, particularly if the feed is mature forage. Plant protein degradation depends on the physical nature of proteins, their release from plant cells, the concentration of proteolytic enzymes and time available for proteolysis. This may not necessarily have a negative impact on the animal if the proteins can be released post-ruminally and thus be available to enzyme digestion (Mueller-Harvey, McAllan, Theodorou and Beever, 1988). However, in tropical straws more than 20% of plant proteins are present in structures such as the vascular bundle sheath which are resistant to microbial attack (Egan, 1985).

2.2.3.2 Plant Consideration

In the presence of adequate rumen nitrogen concentration, microbes will ferment fibre to obtain energy for growth and synthesis of new cells. The by-products of such fermentation include the volatile fatty acids (VFAs) acetate, propionate and butyrate which are the main energy nutrients absorbed in the rumen. Microbial degradation of various plant parts varies from tissue to tissue, decreasing in the order: mesophyll and phloem > epidermis and parenchyma sheath > sclerenchyma and lignified vascular tissue (Akin, 1982). Tropical straws have few mesophyll cell between vascular bundles and have a high proportion of lignified vascular tissue. Both factors combine to lower the degradability of these straws. As plant cells mature, their cell walls thicken and deposition of hemicellulose and lignin increases, further reducing degradability (Akin 1982). Thus diets based on tropical straws should be supplemented or fortified with feedstuffs high in readily degradable tissues.

In addition to adequate nitrogen and energy supplies, rumen microbes require a stable pH environment (6.5-6.9). Production of VFAs tends to lower the rumen pH and thus there is a need to buffer the rumen pH to the optimum level of 6.5-6.8. Straw feeding encourages buffering through increased salivation (Van Soest, 1982) and by the buffering capacity and cation exchange of fibre (McBurney, Allen and Van Soest, 1986).

2.2.3.3 Application of the Theoretical Concept to Practice

There are variations between straws of different origin as far as their nutritional value is concerned (McDowel, Conrad and Harris 1974). Variation could also be caused by varietal differences, season of planting, harvesting conditions and height of cut (Wilson and Brickstock, 1977). The feeding value of straw depends on intake and digestibility (Anderson, 1978) and improvement upon these parameters has been one of the biggest challenges in feeding straws to animals. Chemical treatments and addition of higher quality seeds to straws have been used in designing straw-base diets for ruminants. Chemical treatments rupture the cellulose-lignin complex by extraction or decomposition of lignin and thus make structural carbohydrate more accessible for breakdown by rumen microbes (Smith 1987). Howevers, the use of ammonia either in gaseous form or generated from urea is a weak alkali and therefore cannot break the bond existing between lignin and lignin which strong alkali like NaOH or KOH can break. Supplementation overcomes specific nutrient deficiencies in the diet (Preston, 1986).

A classic case of chemical treatment of straws is reported by Dolberg, Saadullah, Haque and Ahmed (1982) and Wanapat, Praserdsuk, Chanthai and Sivapraphagon (1979). These workers indicated that urea ammoniation increased the digestibility of straw by 10-12% units and also the intake of the ammoniated straw increased significantly.

An example of supplementation is given by Ayoade (1989) who fed maize bran (up to 200g/day) to Malawian indigenous goats given a basal diet of straw. Dry matter intake of the straw was not changed by adding maize bran but total dry-matter intake, and digestibility of dry matter and organic matter, increased. Maize bran presumably supplied readily fermentable carbohydrates which provided energy to the rumen microbes and thus improved cellulolytic activity. The buffering capacity of the straw ensured that rumen pH was not severely lowered and thus fibre digestion was not negatively affected (Van Soest, 1982).

2.2.4 Features of Fermentation in Ruminant Animal Given Basal Diet of Straw Feeds

In order to discuss appropriate strategies for feeding of straw based diets to ruminants, it is necessary to present a view of ruminant digestion and the associated constraints.

2.2.4.1 Energy Transactions in the Rumen

The major energy-providing feed materials in straw are the cell wall constituents comprising mainly cellulose and hemicellulose. These comprise glucose molecules combined in chains with β 1-6 linkage. In general these carbohydrates are insoluble and the initial step in their breakdown is for the cellulolytic organisms to split off cellubiose which is then degraded to give glucose which is further fermented by a series of reactions to give short chain VFA., methane and carbon dioxide (Leng, 1974). Animals do not have enzymes for the hydrolysis of these β 1-6 linkages and depend on micro-organisms in the rumen to carry out this process. The intermediates of this breakdown together with a nitrogenous source are used for microbial cell production. The overall energy losses (as heat) are low and the majority of the energy present in the fermented carbohydrate is retained in the products of fermentation, that is, VFA and microbial cells.

2.2.4.2 Microbial Cell Synthesis

Protein constitutes 30-60% of the dry weight of bacteria and the ash content is often very high (13%) (Czerkawski, 1976) perhaps indicating a large requirement for mineral by rumen organisms.

According to Nolan and Leng (1972) most of the amino acids in bacteria are synthesised from the rumen ammonia pool, but at a maximum some 30% may be synthesised from amino acids of dietary or endogenous origin. The major energy requiring reactions are those associated with amino acid synthesis and polymerisation into protein (Leng, 1982). Leng (1982) further reported that roughly 70% of the available Adenosinse Triphosphate (ATP) is used in microbial protein synthesis and there exists an inverse relationship between VFA production and cell synthesis in the rumen. Thus the higher the VFA production, the lower the microbial cell yield. It has been suggested therefore that when the objective of any feeding strategy is the production of meat, milk and wool, then any manipulation of the diet, or the animal must be aimed at maximising microbial protein output from rumen relative to the energy in the VFA. The opposite will be required by working animal (Leng, 1982).

2.2.4.3 Microbial Cell Turnover in the Rumen

Nolan and Stachiw (1979)have indicated that in sheep on wheat straw-based diet, some 50% of the microbial nitrogen is recycled within the rumen. According to Hespell (1979) this may result from death from starvation of the bacteria when the rumen supply of fermentable substrate is exhausted. This could be the major explanation for the apparent low output of protein from the rumen in animals on straw diets. However, bacteriophages may also destroy bacteria (Adams, Gazaway, Brailsford, Hactman and Jacobson, 1966; Hoogenaraad, Hird, Holmes and Millis, 1967) and the ingestion of bacterial by protozoa (Coleman, 1975) is likely to account for further reduction of the microbial cell turnover depending on the population density of protozoa in the rumen.

The suggestion made here is that, patterns of feed intake on straw diets may cause microbial populations in the rumen to fluctuate with an intermittent death of microbes, largely through lack of substrate. Immediately prior to feeding, the microbial population in the rumen of straw-fed ruminants may be low, which may result in slow colonization of feed materials which will decrease the rate of fermentation. This could lead to low appetite. This situation could be aggravated by the predation of protozoa on bacteria. Nielsen (1981) suggested that readily and totally fermentable cellulolysic source should be added to the straw diet. This may possibly increase the bacterial biomass immediately after feeding and thus potentially increase the rate of colonisation and degradation of the straw particles.

2.3 IMPROVEMENT OF NUTRITIVE VALUE OF STRAWS

2.3.1 Introduction

The nutritive constraints inherent in straw have been dealt with in the preceeding chapters. The main nutritive constraints inherent in straw are high cell wall and low nitrogen contents. These factors limit digestibility and intake and hence limit animal performance. In order to increase the nutritional value of straws a number of processing methods have been employed.

Two fundamental considerations to be made on the feasibility of processing straws are (a) whether the digestibility, and therefore, the ME content of the material is improved by the process and (b) whether the intake of the product is increased.

The improvement of nutritive value of straws can be achieved through: (a) Treatment of the straw to improve biodegradation and (b) appropriate supplementation with additional nitrogen, readily available energy and minerals.

2.3.2. Treatment of Straws

Table 2.4 show a list of available treatments to improve the nutritive value of straws. However, some are not very suitable for use in small scale farming systems.

Table 2.4: Available treatments for improving the nutritive value of crop residues

Physical	Chemical	Physio/Chemical	Biological
1. Soaking	Alkali Treatment		
	1. Sodium Hydroxide	1. Grinding/ Chemical	1. Composting
2. Chopping	2. Calcium Hydroxide	2. Pelleting/ Chemicals	2. Ensiling with animal waste
3. Grinding and Pelleting	3. Potassium Hydroxide	3. Steaming/ Chemicals	3. Fungi Inoculation
4. Boiling	4. Anhydrous Ammonia		4. Enzyme addition
5. Ball milling	Acid Treatment		
6. Gamma irradiation	1. Sulphuric acid		
7. High pressure steaming	2. Hydrochloric acid		
	Oxidation		
	1. Sulphur dioxide		
	2. Ozone		
	3. Chlorinated compounds		

Source: Smith (1987).

2.3.2.1 **Physical Treatment**

Physical treatment has been found to increase intake of crop residues (Chatuverdi, Singh and Ranjhan, 1973; Adu and Lapkini, 1983).

The most commonly used physical treatment has been grinding to reduce particle size and increase the surface area of the roughage exposed to rumen microbial action. Several reviews have summarised the effect of grinding straw (Greenhalgh and Wainman, 1972; Swan and Clarke, 1974 and Minson, 1982). Generally, grinding increases DM intake but some reduction in digestibility is to be expected because of increased rate of passage.

Montgomery and Baumgart (1965), Swan and Clark (1974), have also reported on the beneficial effect of pelleting on intake, probably because that eliminates dustiness due to grinding.

Charturvedi, Singh and Ranghan, (1973) reported increased digestible organic matter and hence intake after soaking straw in water. Effects on nitrogen retention were however variable.

Gamma irradiation, according to Doyle, Devendra and Pierce (1986), may reduce resistance of fibrous residues to physical degradation without necessarily grinding it fine. McManus, Manta and Gray, (1972) indeed noted that irradiated rice straw had a shorter mean retention time in sheep than non-irradiated straw suggesting that irradiation rendered straw more susceptible to physical breakdown. However, *in vivo* results do not confirm these apparently beneficial effect, since the irradiation has been shown to depress dry matter digestibility and to have no effect on voluntary intake.

2.3.2.2 Chemical Treatment

The three classes of chemicals being used to treat fibrous residues are alkalis, acids and oxidising agents. All th ee are capable of weakening cell wall's ligno-cellulose complexes and increasing the swelling capacity of the cell wall thus facilitating microbial enzyme entry (Smith, 1987).

Among the chemical commonly used in the treatment of straw in Ghana include sodium hydroxide (NaOH) (Ibrahim and Pearce, 1982; Amaning-Kwarteng, 1986) caustic ash of some crop residues (Smith and Osafo, 1987) and ammonia derivatives (Sundstol and Coxworth, 1984; Quashie, 1993).

2.3.2.3 Use of Sodium Hvdroxide

Amaning-Kwarteng (1986) and Ibrahim and Pearce (1982) have reported substantial increases in *in vitro* as swell as *in vivo* digestibility and intake of the treated crop residues. The response obtained with *in vivo* digestibility correspond with the *in vitro* DM digestibility (IVDMD) quite well at levels up to 4-6% NaOH. Above this level, *in vivo* digestibility, voluntary intake and increased daily liveweight gain tend to level off or even decrease while the IVDMD continues to increase. Jackson (1977) suggested that the lower *in vivo* digestibility may be related to high rate of feed from the rumen at high levels of Na0H application.

The feeding value of Na0H treated straw has also been investigated by Thompson (1976). The author concluded that the use of alkali treatment straw in practical feeding has been somehow restricted due mainly to the unreacted NaOH and sodium ions from the reacted alkali. Bolsen (1983) had reported that straw treated with 5% NaOH contains approximately 25g Sodium per kg straw and this quantity is effectively absorbed and excreted in the urine: Stigsen (1978) suggested that base excretion at high intake of sodium is regulated by changes in diuresis. This process was found by the author to affect the metabolism of the other minerals. Bolsen (1983) observed a lower energy utilisation and increase in diuresis after feeding alkaline treated straw to sheep.

The above results regarding the feeding value and mineral metabolism of NaOH treated straw together with the problem of cost, availability and handling of the chemical show that it may be necessary to restrict the use of the treated straws or find an alternate method for treating the straw.

2.3.2.4 Use of Caustic Ash of Some Crop Residues

Adebowale (1985) reported levels of potash in the ash of a number of crops residues. Potassium concentration in cocoa pod ash for example was 44mg/kg. The amount of hydroxyl ions (OH^-) present in the ash solution as NaOH and KOH was 20.5 and 28.7% respectively.

Smith and Osafo (1987) using cocoa pod ash solutions as a treatment medium for crop residues, reported a linear increase in the rumen degradability of the dry matter, acid detergent fibre and neutral detergent fibre of residues treated with cocoa pod ash solution equivalent in alkalinity to 2, 4, 6 and 8% NaOH.

Even though the use of crop residue ash solution as alkali for treating crop residue may sound a better alternative to NaOH treatment, these fibrous by-products are used by local farmers for the production of soap, an industry which is regarded as an additional source of income for the farmers.

2.3.2.5 Use of Ammonia

Ammonia in various forms is used to treat straws. These include anhydrous and aqueous forms and indirectly generating ammonia through the use of urea or urine.

The use of ammonia as an anhydrous gas or as aqueous ammonia has improved digestibility and Voluntary intake similar to that achieved with NaOH when conditions for treatment were appropriate (Sundstol , Coxworth and Mowart, 1978). The use of ammonia also avoids the problems arising from the use of NaOH (e.g. accumulation of residual alkali).

2.3.2.6 Urine Treatment

Coxworth and Kullman (1978) compared cattle urine with urea plus jackbean meal and with ammonia. Urine gave as good improvement in OMD and nitrogen content as the other methods provided sufficient quantities were added. These authors further stated that urine is a good source of urease enzyme but large amounts of soluble ash should be added if it is to be used as the sole source of ammonia. By this addition mineral demands will be met. In Bangladesh, rice straw treated with animal urine and ensiled for 20 days showed an increase in nitrogen content from 0.53% to 0.90%. The DM intake in sheep increased by 70% (Saadullah, Haque and Dolberg, 1980). These advantages notwithstanding, the greatest drawback is the collection of urine even from stall fed animals.

2.3.2.7 Urea Treatment

When urea is decomposed it forms ammonia according to the formula:

$$H_2N\text{-}\overset{\overset{\displaystyle O}{\|}}{C}\text{-}NH_2 \; + \; H_20 \; \text{----->} \; 2NH_3 \; + \; CO_2$$

Molecular weight of compound	60	18	17	44
Weight produce	60	18	34	44

Thus adding 6.3% (Wt/wt) of urea is equivalent to adding 3.5% ammonia, assuming 100% conversion (Sundstol and Coxworth, 1984). The application of urea has developed in two directions; (a) Industrial processing of straw combined with pelleting (Marienburg and Begner, 1973) (b) Farm scale production of mixing urea solution with straw and leaving it for some time to allow the enzyme urease to decompose urea and produce ammonia, (Ahmed and Dolberg, 1980). Since in these treatment methods ammonia is only released after the straw has been mixed with urea and it is safely within the confines of a pellator, silo or bag, these are inherently much safer methods of treatment than those requiring handling of anhydrous or aqueous ammonia.

According to Cloete and Kritzinger (1984) and Guessons, Rihani, Kabbali and Johnson, (1989), success with urea treatment depend on urea level, length of treatment, moisture content of straw, environmental temperature and urease activity. Quashie

(1993) reported that urea level of 6.5% and twenty one days treatment period are the optimum condition for urea treatment in Ghana using concrete culvert lined with polythene.

2.3.2.7.1 Effect of Urea Ammoniation on Feeding Value of Straw And On Animal Performance

Response parameters used to assess the effect of urea ammoniation on animal performance include intake, liveweight gain and digestibility.

Mosi and Lambourne (1982) found that the intake and digestibility of teff straw, oat straw and mixed legume haulms are approximately double when such straws were ensiled for 3-6 weeks with 4% (wt/vol) fertilizer-grade urea. Sheep fed on the ensiled product gained 80g/day during a 21 day feeding period compared with a gain of 20g/day in the control animals.

Saadulla, Haque and Dolberg, (1982) measured the effect of different silo on the intake and digestibility of rice straw treated with urea in various ways. The results obtained indicated bamboo seemed as good 'silo' for urea treatment of straw as did the earthen pit (See Table 2.5). The advantage of using 5% instead of 3% was marginal in terms of digestibility although intakes were higher in the 5% treatment. Saadullah *et al.*, (1982) found a 6% unit increase in the *in vivo* DM digestibility when untreated rice straw was supplemented with urea at feeding, but 11% unit increase was observed when the straw was ensiled with urea for ten days. Studies by other workers (Wanapat, Praserdsuk, Chanthai and Sivapraphagon, 1979) have indicated that ensiling straw for 2-3 weeks with urea (3-5%) at 50% moisture content increased the digestibility by 10-12% units. Ibrahim, Fenando and Fenando (1983) studied a number of sources of urease enzyme and their influence on the effect of urea ammonia treatment of straw. The authors observed that inclusion of a urease source reduced the treatment time to less than 5 days compared to 21 days without urease. These findings have been confirmed by Quashie (1993) in Ghana. The author found the optimum treatment time for rice straw ensiled with urea to be 21 days without any additive.

Table 2.5: **Protein content, intake (OMI)* and digestibility (OMD)** of urea-treated rice straw**

Form of Rice Straw	Crude Protein g/kg DM	OMI g/kg $W^{0.75}$/d	OMD %
Untreated	33	46.2	45
Treated with 3% urea in earthen pit (20 days	74	51.7	54
Treated with 5% urea in earthen pit (20days	80	60.9	56
Treated with 5% urea in earthen pit (40 days) + 10% molasses	78	63.4	57
Treated with 5% urea in bamboo basket (20 days)	83	57.5	56

* OMI = Organic Matter Intake
** OMD = Organic Matter digestibility

Source: Saadullah *et al.*, (1981)

2.4 SUPPLEMENTATION

2.4.1 Introduction

Various pre-treatment methods reviewed earlier to a limited extent, break the physical barrier to digestion of straws. The optimum utilisation of the fibre is limited by nutrient deficiencies which indirectly impair microbial activity and directly affect the nutritional status of the animal.

Smith (1987) observed that chemical treatment may improve intake and digestibility but unless adequate supplementation of deficient nutrient is made, much of the energy released will be inefficiently used. Devendra (1985) has pointed out that the characteristics of a maintenance feed for adult ruminants are: a crude protein level of 6-7%, a dry matter digestibility of 50-55% and a dry matter intake of about 1.7% of body weight. Data summarised in Table 2.6 show that crop residues rarely meet these requirements and therefore adequate supplementation will have to be made. Table 2.7 shows a list of some of the potentially valuable supplements.

Table 2.6: Voluntary intake and digestibility of selected crop residues

Crop Residue	% CP	Intake % BW		Dry Matter Digestibility		Source
		Sheep	Goat	Sheep	Goat	
Maize Stover	4.0		0.7		53	1
Sorghum Stover	4.0		2.0		57	1
Rice Straw	4.2	1.4	1.9	47	48	2
Cocoa Pod	5.0			20		3

Source: 1. Alhassan *et al.*, 1984
2. McManus *et al.*, 1972
3. Smith and Osafo, 1987

Table 2.7: Possible sources of nutritional supplements to straws in Ghana

Nutritional Factor	Source
Fermentable Nitrogen	Urea, urine, animal manure, ammonium sulphate.
Fermentable Carbohydrate	Molasses, cassava chips, cassava peels, maize bran, rice bran
Roughage-micronutrient	Forages such as Gliricidia, Leucaena, cassava tops, sugarcane tops, sorghum tops, banana leaves and pseudostems.
By-pass protein	Oil seed cakes, fish meal, leucaena, Gliricidia and other tannin rich forages
By-pass energy	Starch, corn, broken rice, rice polishing.

Source: Compiled from Preston and Leng (1987)

2.4.2 Urea Supplementation

Urea supplementation at the rate of 1 per cent of diet dry matter can be expected to increase rate of gain of young stock by about 0.1 kg per day (Gupta *et al.*, 1971; and Khurana, 1978). This amounts to a doubling of growth rate in many instances and thus halving of time taken to achieve maturity.

Urea supplements provide the animal more protein via microbial protein synthesis in the rumen. Thus rate of gain and milk production increase. Urea also increases dry-matter intake by between 14-35% (Sharma Thauwar and Taparia, 1972; Khurana, 1978; Gadre, 1979). Gadre (1979) observed that the change in digestible energy intake however may range from (-) 15 to (+) 15 percent MJ because increase DM intake is sometimes accompanied by a fall in digestibility. He attributed the fall in the digestibility to the occasional high concentrations of ammonia in the rumen which becomes toxic to the animal. He further suggested that application of urea should be little but frequent and also mixed thoroughly and uniformly with the straw before feeding.

2.4.3 Energy Supplementation

Supplementary energy such as maize grain has been found to improve feed conversion efficiency in cattle fed wheat straw (Donefer, 1972). According to Hespell (1979) about 60% of the rumen bacterial population die and about 30% or more lyse within 2 hours due to starvation in the absence of a fermentable energy substrate. The author therefore suggested that with untreated crop residue, it is likely that provision of readily available carbohydrate may improve the utilisation of ammonia for cell growth.

Another example of energy supplementation is given by Ayoade (1989) who fed maize bran (up to 200g/day) to goats fed a basal diet of pigeon pea (*Cajanus cajan*) pods. Dry matter intake of the pods was not changed but total dry-matter intake, and digestibility of dry matter as well as organic matter, increased. Maize bran presumably supplied readily fermentable carbohydrate which provided energy to the rumen microbes. Small quantities of maize bran has been reported to improved cellulolytic activity.

Nuwanyakpa and Butterworth (1987) found that supplementing a diet of teff straw with molasses increased total feed intake and apparent digestibility of dry matter, neutral detergent fibre and nitrogen. The "value of molasses" is due to the presence of sulphur.

2.4.3.1 Molasses as an Energy Supplement

Various studies have demonstrated improved animal performance from dry season supplementation with molasses (Sansoucy and Arts, 1986; Topps 1976; and Nuwanyakpa and Butterworth, 1987).

Supplementation with urea/molasses in liquid has been proposed as a method of overcoming the loss of animal production and many studies have been reported (Chicco, Shultz, Carnevalia and Ammerman, 1972). The effects have generally been considered to be beneficial. However, there are some limitations to the use of the solution. These arise from the difficulties in controlling intake, achieving good distribution of the supplement throughout the herd, and handling the molasses. It has been suggested that the molasses should be fed as block (urea/molasses) and these have usually yielded satisfactory results (Sansoucy *et al.*, 1986; Preston and Leng, 1987; and Munthali *et al.*, 1991). Munthali *et al.*, (1991) explained that the readily fermentable carbohydrate in the molasses promoted the efficient use of ammonia from the urea by rumen microbes. Siebert and Kennedy (1972) further attributed the nutritive value of molasses to the presence of sulphur in the molasses. These authors showed conclusively that sheep given low quality roughage would respond to urea supplement provided sulphur was not limiting. Greater weight losses were also reported with maize supplement than molasses supplement Schlink (1980) as cited by Amaning-Kwarteng, (1986). The superiority of molasses to maize was related to the lower sulphur content of maize.

2.4.4 Sulphur In Ruminant Diet

With the increased use of urea as a partial nitrogen replacement for protein nitrogen, it has been realised that the amount of sulphur present in the diet may be the limiting factor for the synthesis in the rumen of cystine, cysteine and methionine. Under these conditions, the addition of sulphur to urea containing rations may be beneficial.

The capacity of sheep to utilise wheat straw treated with sodium sulphate has been studied by Bird (1973). The addition of sodium sulphate at a level of 0.4% of the dry matter, significantly increased the intake of energy, the efficiency of digestion and the liveweight gain as shown in Tables 2.8 and 2.9. In another development Bauchop (1979) and Muon, Orpin and Hall (1981) found no difference existing in bacterial population between sheep fed either sulphur supplemented forage or unsupplemented forage. There were however, marked differences in the prevalence of sporangia and zoospores typical of rumen fungi. Evidence of rumen fungi was always found with sheep fed sulphur supplemented forage but few or none were seen with unsupplemented forage suggesting that ingestion of sulphur stimulates rumen fungi. Bauchop (1979) observed that the heavy colonisation by rumen fungi of lignified cell walls and also presence of sporangia adhered to forage fibre suggested a possible role in degrading ligno-cellulose structure. *In vitro* test for dry matter loss carried out by Akin and Horgan (1983) showed that rumen fungi in the absence of actively growing bacteria could remove about 60%. These observations noted above established the unique role of sulphur in influencing rumen fungi to attack and weaken ligno-cellulose tissues in the rumen.

Table 2.8: Intake and digestion of wheat straw supplemented with either nitrogen or nitrogen together with sulphur by sheep

Parameter	Raw Straw	Straw + Nitrogen	Straw + Nitrogen + Sulphur
DMI (g/day)	330	570	810
App. Digestibility (%)	39.1	42.80	50.9
OMI (g/day)	313	537	760
OMI (g/kg W/day)	13.18	20.40	27.04
OM digested (g/day)	125	247	391
OM digested (g/kg W/day)	5.28	9.25	13.87
Digested Energy (KCal/day)	535	1108.0	1790
Digested Energy (KCal/kg W/day)	22.8	41.48	63.54

Nitrogen = 2% Urea
Sulphur = 0.4% Na_2SO_4

Source: Bird, (1973)

Table 2.9: Intake and retention of nitrogen by sheep fed wheat straw supplemented with 1, nitrogen and 2, nitrogen plus sulphur

Parameter	Raw Straw	Straw + Nitrogen	Straw + Nitrogen + Sulphur
Nitrogen Intake (g/d)	0.83	7.91	11.76
Nitrogen Intake (mg/kg W/d)	35	297	418
Urinary nitrogen (g/d)	1.44	6.24	6.80
Urinary nitrogen (mg/kgW/d)	61	234	243
Faecal nitrogen (g/d)	1.71	3.31	4.46
Faecal nitrogen (mg/kgW/d)	68	166	182
Nitrogen balance (g/d)	-2.31	-1.63	0.50
Nitrogen balance (mg/kgW/d)	-97	-62	17
Liveweight gain (g/d)	-231	-25	114
Liveweight gain (mg/kgW/d)	-9.85	-0.91	3.92

Nitrogen = 2% urea
Sulphur = 0.4% Na_2SO_4
Source: Bird, 1973

2.5 The use of nylon bag *(in situ)* technique for feed evaluation

The nylon bag technique has been used for many years to provide estimates of rate and extent of disappearance of feed constituents from the rumen (Merez, Orskov and McDonald, 1977). Under certain dietary and production conditions, ruminant diets must be supplemented with forms of rumen non-degradable nutrients ("by-pass" nutrients) to increase the efficiency of nutrients utilisation and hence production (Preston and Leng, 1984). Thus there is a need for a technique to quantify the potential degradability in the rumen of feed supplements. Comparisons of results from different nylon bag experiments is complicated to some extent by certain factors including differences in bag size, porosity of bag material and time of incubation in the rumen (Merez *et al*, 1977). Several workers have suggested incubation time up to 96 and 48 hours for roughage and concentrate diets respectively (Orskov, Hovell and Mould, 1980).

Even though the nylon bag technique provides a powerful tool for initial evaluation of feedstuffs, there are some limitations as well (Meyer and Mackie, 1986; and Nocek, 1988). Firstly, since the sample is confined within the bag, it is not exposed to any breakdown due to chewing and rumination and secondly, food would normally be able to leave the rumen once broken down to a suitable particle size. With these reservations, the results must therefore be treated with due caution.

CHAPTER THREE

EXPERIMENT I

3.0 TITLE: A study on the feeding values of untreated straw (US), Urea-ammoniated straw (AS) and straw supplemented with urea-molasses block (UMBS)

3.1 INTRODUCTION

Despite their widespread use and availability, straws have severe limitations for ruminants. Various physico-chemical processing techniques for delignification and/or protein enrichment by non-protein nitrogen (NPN) incorporation have been experimented with and used to upgrade the nutritive value of straw (Jackson, 1978; Sundstol, Coxworth and Mowart, 1978 and Quashie, 1993). Energy supplements have also been used to improve the utilization of straws. However, their use depends on availability, potential fermentability and price (Preston and Leng, 1987).

Feeds available as energy source include maize, molasses, brewers grain and cassava. Schlink (1980) as cited by Amaning-Kwarteng (1986), compared the effect of molasses and maize grain as energy supplements for cattle consuming spear grass (*Heteropogon contortus*) *ad libitum*. Greater weight losses were reported with maize than molasses. This observation coupled with the relatively lesser demand for molasses for human consumption than maize grain renders the former a better choice for supplementation in ruminant nutrition in Ghana. Urea was also chosen for treating the straw because apart from its ability to increase the nitrogen content of the treated material, it is being promoted as a fertilizer and hence is readily available in the country, and farmers can handle it safely.

The objective of this study was to investigate and then quantify and compare the potential of these diets in reducing dry-season weight-loss by calculating Metabolisable Energy consumption by the sheep (MEI) relative to their Maintenance Energy requirement (Mm).

3.2 MATERIALS AND METHODS

3.2.1 Animals and Management

3.2.1.1 Digestibility Studies

Six Nungua Black Head x Djallonké wethers weighing an average of about 24kg liveweight were used. Three of the sheep were fitted with permanent rumen cannulae (6.4cm diameter). The other three sheep remained intact and were each paired with the fistulated ones for the study. They were housed in individual metabolism cages.

The study had three periods; each made up of ten days adaptation and seven days for sample collection. Feed intakes were measured daily and refused samples collected daily and bulked. Subsamples were taken at end of trial and dried at 50°C. Dried samples were bulked for each animal over the collection period.

3.2.1.2 Growth Studies

Twelve Nungua Black Head x Djallonké wethers (average weight of 20kg) were used to measure growth response to the experimental diets (3.2.2). The wethers were housed in individual pens with concrete floors, asbestos roofing and sides made of wooden rails. Each pen had a permanent feed trough at one end and a water trough at the other. No bedding was provided.

Two weeks prior to the commencement of the experiment the sheep were injected with polyvitamin suspension (Multiplex forte, West Germany) and treated for ectoparasite with 'Bayticol' (Bayer Leverkusen) and endoparasite with Abendazol (Dapharama, Raamsdonskeveer, Holland).

3.2.2 Diets

Rice straw (local variety from Kpong Farms) was coarsely chopped (2-4 cm pieces) and prepared to constitute three experimental diets/treatments, US, AS and UMBS.

3.2.2.1 Untreated Straw (US)

Untreated straw was chopped and fed as such without any dietary supplement. This diet served as the control.

3.2.2.2 Ammoniated Straw (AS)

Chopped straw was spread in a concrete culvert (2½ x 50 x 100cm) lined with polythene sheets and each layer of 14kg straw (DM basis) sprayed with urea solution (72.3g Urea in 498.2ml water/kg straw) and rammed down. Each culvert containing 70kg straw was then covered with polythene sheets, followed by heaps of soil and left for 21 days before removal as done by Quashie (1993). Treated straw was, after removal from culvert, aired for 24 hours before feeding.

3.2.2.3 Straw supplemented with Urea-Molasses Block (UMBS)

Chopped untreated straw was supplemented with urea-molasses blocks (UMBS) at time of feeding. The blocks were prepared with the composition shown below:

Table 3.1: Composition of Urea-Molasses block

Ingredient	Content	
	Kg	%
Molasses	20	40
Urea	3	6
Salt (NaCl)	2	4
Wheat Flour	5	10
Cement	4	8
Copra Cake	6	12
Wheat Bran	10	20
Total	50	100

3.2.3 Experimental Design and Statistical Analysis

3.2.3.1 Digestibility Studies

The three fistulated and three 'intact' sheep forming three pairs were assigned to the Experimental Diets US, AS and UMBS in a two 3 x 3 Latin Square design.

3.2.3.2 Growth Trial

Three groups of four animals were assigned to each of the experimental diets in a randomised complete block design for 10 weeks to evaluate the effect of the diets on growth rate and feed conversion efficiency. The animals were allowed one month tc adapt to the diet before the experiment began. Live weight was measured every two weeks after a 12 hour starvation period. During this period the animals were allowed out for exercise.

Water and mineral licks were provided *ad lib* to all animals during both digestibility and growth studies. The lick had the following composition (mg/kg): Mg (2500); Fe (1800); Mn (380); Zn (280); Co (110); I_2 (110) and Se (3).

3.2.4 Chemical Analysis and Calculations

Feed, refusals and faecal samples were analyzed for dry matter (DM) by drying in an oven to a constant weight at 50°C. Organic matter (OM) was determined as DM less the residual ash obtained after ashing at 550°C for 6 hours. Nitrogen was analyzed by a micro-kjedahl technique. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by the method of Goering and Van Soest (1970).

OM in feed and faeces, DM intake and Digestible OM in dry matter (DOMD) were thus determined. These data were used according to Ministry of Agriculture, Food and Fishery, MAFF (1975) to calculate Metabolisable Energy Intake (MEI) and then estimated the ratio of MEI to Metabolisable Energy required for maintenance (Mm) for each diet. Where the ratio was found to be greater than one for any particular diet, that diet was considered adequate to meet maintenance requirement.

Calculations:

MEI = DOMD x 0.15 x DMI (MAFF, 1975)

Mm = 1.2 + 0.13 (Bodyweight in kg) (MAFF, 1975)

3.2.5 Statistical Analysis

The data were all subjected to analyses of variance and treatment means, where necessary, compared on the basis of the Student-Newman-Keul's test.

3.3 RESULTS

3.3.1 Chemical Composition

Table 3.2 shows the effect of urea ammoniation on the chemical composition of rice straw. The treatment resulted in 10.9% and 48.5% reduction in NDF and Hemicellulose content respectively. These reflected in 12.3% increase in cellulose. Crude protein (CP) content of treated straw also showed approximately a 2.5 fold improvement. Table 3.2 also shows the chemical composition of the urea-molasses block (UMB). The significant feature is the high crude fibre (CF) (30%).

3.3.2 Intake and Digestibility

Dry matter intake (DMI), apparent digestibilities and digestible nutrient intakes are shown in Table 3.3. DMI per kg body weight was found to be 52.45, 71.46 and 65.78 g/d by sheep fed Diets US, AS and UMBS respectively. The difference between AS and UMBS were not statistically significant (P>0.05). Both values were however significantly (P>0.05) higher than US (P<0.05). Diets AS and UMBS showed significantly (P<0.05) higher values for all the nutrients than diet US. The difference in crude protein and cellulose between diet AS and UMBS were significant (P<0.05) while the differences were not significant (P>0.05) for organic matter and NDF. The values for digestible nutrient showed a similar trend.

3.3.3 Growth Studies

Average initial body weight in groups US, AS and UMBS were 18.65, 20.77 and 21.00 kg respectively. The weight of animals fed diet US was significantly (P<0.05) lower than the other two groups. The respective final weights were 19.40, 25.80 and 25.82kg (Table 3.5). There was thus a gain in body weights of 10.70, 72.0 and 68.92 g/d over the ten weeks period for the three respective groups. There was significant (P<0.05) difference between animal on US and the other two groups.

Whilst animals on AS and UMBS did not show any significant (P>0.05) difference in feed conversion efficiency, they both showed significantly (P<0.05) higher values than animals on US.

3.3.4 Metabolizable Energy

Table 3.5 shows digestible organic matter in Dry matter (DOMD) and the ratio of MEI to Mm. MEI for animals fed ammoniated and urea-molasses supplemented rice straw were significantly ($P < 0.05$) higher than animals fed untreated straw. Mm did not show any significant difference among the diets. The ratios MEI:Mm were above one for both the ammoniated diet (AS) and urea-molasses supplemented diet (UMBS) whilst untreated straw (US) significantly ($P < 0.05$) showed the lowest value of 0.76.

Table 3.2: Chemical composition of untreated and urea ammoniated rice straw and urea-molasses block

Chemical component	Untreated rice straw	Urea ammoniated rice straw	Urea-molasses block*
Dry matter (DM) (%)	89.9	75.00	89.7
Composition on DM Basis (%)			
Crude Protein	3.8	8.5	28.0
NDF	78.5	69.9	
ADF	58.3	59.8	
Hemicellulose	20.2	10.4	
Cellulose	35.0	39.3	
Lignin	8.5	9.6	-
Organic Matter	77.6	78.9	80.44
Crude Fibre			30.0

*The block after formation was left for weeks to dry before feeding.

Table 3.3: Dry matter intake (DMI), apparent digestibility and digestible nutrient intake by sheep fed untreated, urea ammoniated and urea-molasses supplemented rice straw.

Parameter	Untreated rice straw	Urea ammoniated rice straw	Urea-molasses supplemented rice straw	S.E (df)
DMI (g/d)	555.29[A]	768.58[B]	707.24[B]	18.421 (123)
(g/kg BW)	52.45[A]	71.46[B]	65.78[B]	1.144 (123)
Apparent Digestibility %				
OM	48.25[A]	62.26[B]	65.93[B]	2.567 (15)
CP	49.78[A]	73.88[B]	67.01[C]	1.621 (15)
NDF	54.26[A]	71.61[B]	71.41[B]	3.119 (15)
Cellulose	44.91[A]	68.40[B]	60.03[C]	2.050 (15)
Digestible Nutrient Intake (g/d)				
OM	211.73[A]	371.25[B]	360.43[B]	24.293 (15)
CP	16.53[A]	48.55[B]	27.55[C]	2.685 (15)
NDF	246.00[A]	384.26[B]	397.00[B]	31.852 (15)
Cellulose	91.05[A]	207.20[B]	149.90[C]	14.609 (15)

Note: Means in the same row with different superscripts are significantly different ($P<0.05$)

Table 3.4: Mean liveweight gain and feed utilization of sheep fed untreated, urea ammoniated and urea-molasses supplemented rice straw.

Parameter	Untreated Rice Straw	Urea Ammoniated Rice Straw	Urea-molasses Supplemented Rice Straw	S.E. (9 d.f)
Number of Sheep	4	4	4	
Dry Matter Intake (g/d)	559.97[A]	780.12[B]	715.50[C]	3.185
Initial Liveweight (kg)	18.65[A]	20.77[B]	21.00[B]	0.536
Final Liveweight (kg)	19.40[A]	25.80[B]	25.82[B]	0.602
Average daily gain (g/d)	10.70[A]	72.0[B]	68.92[B]	4.820
Feed Conversion ratio (kg feed/kg wt gain	60.40[A]	10.70[B]	10.40[B]	7.814

Note: Means in the same row with different superscripts are significantly different ($P<0.05$)

Table 3.5: Metabolizable Energy Intake (MEI) relative to Maintenance Energy Requirement (Mm) by sheep fed the experimental diets

Parameter	Untreated rice straw	Urea-ammoniated rice straw	Urea-molasses supplemented rice straw	S.E. (15d.f)
Average liveweight (kg)	24.00	24.20	24.10	
DOMD (%)	37.60[A]	48.48[B]	51.15[B]	1.844
MEI (MJ/d)	3.16[A]	5.51[B]	5.57[B]	0.342
Mm (MJ/d)	4.33[A]	4.33[A]	4.28[A]	0.276
MEI: Mm	0.76[A]	1.29[B]	1.25[B]	0.109

DOMD = Digestible Organic Matter in Dry matter.

MEI = DOMD x 0.15 x Dry matter Intake (MAFF, 1975).

Mm = 1.2 + 0.13 (Bodyweight in kg) (MAFF, 1975).

*Means in the same row with the same letter are not significantly different ($P>0.05$).

3.4 DISCUSSION

Chemical Composition of Ammoniated and Untreated Straw:

The data in Table 3.2 show that ammoniation increased the crude protein content of the straw by 2.5 fold. Toro and Majaamker (1987) reported a 3-fold increase in crude protein content of paddy straw when treated with urea for 30 days. Several other workers have reported an increase in nitrogen content of ammoniated materials (Garrett, Walker, Kohler and Hart, 1979; Gadre and Jackson, 1980; Kianyi, 1981; Mira, Kay and Hunter, 1983; William, Innes and Brewer, 1984ab; Sundstol and Coxworth, 1984; Srivastrava, 1988 and Quashie, 1993). Hemicellulose content decreased owing to ammoniation by about 50 percent. Comparable reduction in the hemicellulose content of ammoniated low quality roughages were reported by Horton (1981), Abadin and Kempton (1981) and Ibrahim and Pierce (1983). Abadin and Kempton (1981) reported a 40 percent reduction in the hemicellulose content of barley straw ammoniated with anhydrous ammonia. The reduction in NDF and increase in ADF contents after treatment are similar to the results of others (Oji and Mowart, 1979; Solaiman, Horn and Owens, 1979; and Brown, Philips and Jones, 1987). These observations were however in contrast with the results of Buether, Lechtenburg, Hendrix and Hertel (1982) and Zorrilla-Riose, Owens, Horn and McNew (1985) who showed slight decreases in ADF and lignin contents after ammoniation. Generally, changes in ADF and lignin after ammoniation have been inconsistent in the literature. Van Soest, Mascarenhas Ferreira and Hertley, (1984) suggested that changes in lignin percentage is not a meaningful measure of treatment. In contrast to ADF and lignin, NDF percentage has always decreased with ammoniation. This decrease has been attributed to hemicellulose solubilisation during ammoniation (Horton, 1981).

Intake:

The dry matter and digestible nutrient intakes as shown in Table 3.3 indicate that urea-molasses supplementation improved voluntary intake of the straw by about 20%. Digestible OM, CP, NDF and Cellulose were improved by 41.2, 40.0, 38.0 and 39.2% respectively. These results agree with that of Muthali *et al.*, (1991). They found that supplementing a diet with molasses increased total feed intake and apparent digestibility of dry matter. Blaxter and Wilson (1963) and Lamb and Eadie (1979) also indicated that energy supplementation had invigorating effect on the intake of some poor quality straws. It has been shown that steers fed rice straw supplemented with corn gluten meal consumed 10.4% more straw than steers fed only untreated straw (Zorrilla-Riose, Horn, Philips and McNew, 1990). These authors gave the nitrogen content of the straw as 3.8%. In the present study the nitrogen content of the straw was only 0.61%. Several reporters (Preston and Leng, 1984) have shown that when the rumen nitrogen content is limiting, non-protein nitrogen (NPN) and energy supplementation lead to greater improvement and intake of low quality roughage by ruminants. Hence in the present study intake was improved by 20%. The reason for this increase may be that, the urea and sulphur components of the urea-molasses block stimulated more microbial fermentation in the rumen. Schlink (1980) as cited by Amaning- Kwarteng (1986) reported that molasses contained substantial amount of sulphur which plays a very important role in ruminant nutrition especially sheep. Sulphur stimulates rumen fungi which cause significant degradation of fibre by attacking and weakening lignocellulose tissues in the rumen (Akin and Horgan, 1983). The more fragile residue resulting from the attack by fungi could therefore explain the appreciable intake consistently observed in sheep eating urea-molasses supplemented diet compared with those on raw diet. Rees, Minson and Smith (1974) had also shown that sulphur supplementation reduced retention time of forage in the rumen and increased voluntary intake compared with diets without sulphur.

Voluntary intake of ammoniated straw was 39.3% higher than that of untreated straw. Comparable results on urea ammoniation were published by Oji, Mowart and Winch (1977); Wanapat *et al.*, (1979); Hadjipanayiotu (1982) and Singh and Gupta (1987). Zorrilla-Riose, Horn, Philips and Hibberd (1984) suggested that higher intakes of ammoniated materials can be partially attributed to an increase in availability of nutrients due to the solubilisation of hemicellulose, by exposure of more surface area for microbial action; by additional supply of nitrogen for rumen microbial growth; and by faster rate of removal of the undigested fractions from the rumen.

In an experiment by Cloete, De Villiers and Kritzinger (1983), the intakes per unit body weight of ammoniated and urea supplemented straws were found to be 27% in favour of ammoniated diet. In the current work, the difference between ammoniated diet and urea-molasses supplemented diet was only 5.8%. The level of ammoniation in the former was 70g urea/kg straw as against 72.3g urea/kg straw in the present study. This difference between the ammoniated and urea-molasses supplemented diets was not much compared to that of Cloete *et al* (1983). This observation further confirms the superiority of urea-molasses mixture to urea alone as a supplement to low quality roughages in ruminant diet. The higher intake of AS compared to UMBS could be due to the solubilization of fibre component in the AS which in turn caused faster rate of removal of undigested fraction from the rumen.

Digestibility:

Urea-molasses supplementation significantly improved the apparent digestibility of OM by 36.6% (see Table 3.3). The above finding agree with other results showing that feeding various energy diets alongside roughages increase OM digestion in the rumen (Hespell, 1979). An improvement of 22.5% OM digestibility was obtained with ammoniated diet when compared with the untreated straw. Similar results have been reported by Saadullah, Haque and Dolberg (1982) and Hadjipanayiotu (1982). OM digestibility was higher in urea-molasses diet than ammoniated diet, though not significant ($P > 0.05$). Mould *et al.*, (1983) and Anderson, Merill, McDonnell and Klopfenstein (1988) found that OM digestibility was significantly improved by 48% when stargrass hay was fed with molasses compared with ammoniated hay fed alone.

Crude protein digestibility however was significantly higher in ammoniated diet than urea-molasses supplemented diet. This was also associated with a higher ($P < 0.05$) intake of digestible crude protein (Table 3.3) indicating effective utilisation of nitrogen by sheep fed urea treated straw in spite of the readily available energy in the urea-molasses block. The observation shows that ammonium hydroxide produced following hydrolysis of urea during treatment well cleaved the alkali labile linkages existing between lignin and structural carbohydrate and paved the way for effective utilisation of the energy from the carbohydrate by the rumen microbes to ferment nitrogen (Buether *et al.*, 1982). The lower nitrogen digestibility of the urea-molasses supplemented diet could further be explained by the observation of Manson (1981). The author suggested that the decrease in apparent digestibility of nitrogen with higher intakes of nitrogen was due to an increase in quantity of water soluble nitrogen of microbial and endogenous origin excreted in the faeces which consequently decrease the digestible nitrogen calculated. The urea-molasses block was found to have a very high crude protein content of 28% as against 8.5% in ammoniated straw (Table 3.2).

Ammoniation significantly ($P<0.05$) improved the apparent digestibility of NDF and cellulose by 31.9 and 52.3% respectively in comparison with untreated rice straw. A corresponding improvement of 0.2 and 13.9% were obtained when ammoniated straw was compared to urea-molasses supplemented straw (UMBS). These latter differences between the NDF contents were however not significant ($P>0.05$). With respect to the lower cellulose and NDF digestion experienced with UMBS compared with ammoniated straw (AS), Mould *et al.*, (1983) explained that the lower values of cellulose and NDF digestion experienced when sheep were fed readily fermentable carbohydrates are due to decline in ruminal fluid pH. In the present work, ruminal pH was consistently lower with urea-molasses supplemented diets (average of 5.4) from that for ammoniated diet (average 7.8) (Fig. 4.5).

Growth Studies

The resulsts indicate that urea ammoniation and supplementation with urea/molasses block improved performance. The consumption of these diets by the animals were relatively higher than the untreated straw. This was associated with improvement in feed conversion efficiency which suggests that improvement in the digestibility of the straw occured. Improvement in the digestibility of the straw after ammoniation and urea/molasses supplementation have been colaborated by Hespell (1979) and Saadullah *et. al.*, (1982).

Sheep fed AS showed greater growth rate than those fed UMBS. This difference could be due to more effective utilizations of nitrogen by sheep on AS than sheep on UMBS as observed by Manson (1981).

Ratio of MEI to Mm:

The improvement in the digestible organic matter in dry matter (DOMD) and metabolisable energy consumed by sheep following urea treatment and urea-molasses supplementation (Table 3.5) show that low quality roughages treated in these ways change from poor quality to medium quality feed which has the potential to meet maintenance requirement. The Ministry of Agriculture, Food and Fisheries, MAFF (1975) proposed that for research purposes, the most useful indicator of feed to meet maintenance requirement is the use of the ratio of MEI to Mm. If the ratio is greater than one, then the feed is adequate for maintenance. Urea ammoniated and urea-molasses supplemented diets in the present studies could provide all the required maintenance energy and even provide for growth (Table 3.4). The ratio for untreated straw was less than one and could therefore not meet the maintenance requirement which is suggestive of the fact that appropriate supplementation should be made before it could be used for ruminants in the dry season for productive purposes. Despite this condition, the animals on US showed slight growth rate. This could be due to grazing when the animals were allowed out for exercising.

The present study suggests that ammoniation and urea molasses block supplementation could improve the feeding value of low quality roughages and form the base for supplementation for dry season ruminant feeding.

CHAPTER FOUR

EXPERIMENT 2

4.0 TITLE: Effect of ammoniation and dietary supplementation on rumen degradation and rumen metabolites in sheep fed rice straw.

4.1 INTRODUCTION

Several systems for evaluation of feed protein and the calculation of protein requirements for the ruminants have been proposed. These include those of RDP-UDP (ARC, 1984) in England and AP-System (NRC, 1985) in the U.S.A. In all these systems, emphasis is placed on the separation of dietary protein into ruminally degraded (RDP) and undegraded (UDP) protein.

For many feedstuffs in developing countries, there are no data available on the extent of protein degradation, thus limiting the widespread application of feed formulation based on RDP and UDP (Kirkpatric and Kennedy, 1987). This is especially true for basal feedstuffs such as roughage (Negi, Singh and Makkar, 1988).

Methods to evaluate feedstuffs include *in vivo* as carried out in the previous experiment, *in situ* (incubation of feeds in bags suspended in the rumen) and *in vitro* (laboratory) techniques. Although the *in vivo* method remains the reference technique, it is a complex, expensive and difficult procedure (Owens, 1987). The *in vitro* has the disadvantage of not presenting what actually happens in the animal. The *in situ* technique has also been criticised (Meyer and Mackie, 1986; Nocek, 1988), but still has the advantage of giving very rapid estimates without necessitating any procedure more complicated than simple weighing.

This study aimed to use the nylon bag (*in situ*) technique to study the degradation characteristics of the experimental diets and thus obtain information related to their nutritive value. Rumen pH and ammonia concentrations changes were also studied.

4.2 MATERIALS AND METHODS

4.2.1 Rumen Degradation

4.2.1.1 Animals

Three rumen-cannulated sheep were used. They were assigned to the experimental diets in a 3 x 3 latin square design.

4.2.1.2 Sample

Two grams each of air-dried urea treated and untreated rice straw, ground to pass through a 2.0mm sieve, were weighed into nylon bags which had been oven dried and weighed (the UMBS was not incubated but rather fed to see its effect on straw degradation in the rumen). DM, N and NDF analyses were performed on the samples prior to incubation and on the residue following incubation.

4.2.1.3 Incubation

The nylon bags (dimension: 8 x 12cm, Pore size: 25μ) containing samples were soaked for 3min. in water to displace air before inserting into the rumen. All samples were incubated in duplicate per sheep and replicated in the three sheep (following the pattern of the 3 x 3 latin square design). Four bags were tied to a drop line consisting of nylon cord (200mm x 2mm) and weighed with a 20g steel bolt at one end. Two drop lines were incubated at a time in the rumen.

4.2.1.4 Removal of Bags

Incubated bags were withdrawn after the following hours of incubation 3, 6, 9, 24, 36, 48, 72 and 96. Retrieved bags were immediately dipped into alcohol (70%) to arrest fermentation. The bags were then washed under running water until water was clear after which they were dried at 50°C to a constant weight.

4.2.1.5 Chemical Analysis and Calculation

The dried residues were analyzed for DM, N and NDF as carried out in experiment one.

The degraded portions for each sample were determined as the difference between the values on the original sample and the dried residue.

For each diet, percent of DM, N or NDF disappearance were plotted against incubation time. The values of percent solubility 'a' (the intercept of the graph on the 'y' axis) and potentially degradable fraction 'b', (the highest point on the graph) were determined. The steepest section of the curves indicating maximum rate of degradation were identified and the percentage degradation (P) and incubation time (t) corresponding to the mid-point of this section were read off; this enabled the degradation rate constant

(c) to be calculated from the following exponential equation (Orskov *et al.*, 1980):

$$P = a + b\,(1 \quad e^{-ct})$$

where P = Potential degradability at time 't'

a = Readily fermentable fraction

b = Potentially degradable fraction (%)

t = Time (eg. 12 hr., 24hr., 48hr., 72hr.)

c = The rate constant for the degradation of 'b'

4.2.2 Rumen Ammonia and pH

4.2.2.1 Rumen Sample

Rumen liquor was collected after the nylon bag studies. The samples were obtained via the cannula by inserting a short tube connected to a suction pump into different location in the rumen. 20ml was collected at each four hour interval and then strained through cheese cloth. Immediately, pH was taken with a pH meter after which two drops of concentrated sulphuric acid were added and frozen to await ammonia analysis.

4.2.2.2 Chemical Analysis and Calculations

The frozen samples were thawed and then centrifuged at 3000r.p.m. for 10 min. and a 5ml aliquot distilled for 5 minutes using Makhan's steam distillation with 2ml 40% sodium hydroxide. The distillate was collected in 5ml of 2% boric acid solution and then titrated against 0.0142N H_2SO_4.

Ammonia - N concentration per 100ml rumen liquor (AC) was calculated by the following equation.

$$AC = \frac{X \times 0.2 \times 100}{5}$$

where X = titre value in mls.

4.3 RESULTS

4.3.1 Rumen Degradation

The extent of ruminal degradation of roughage DM, NDF and N as affected by ammoniation and urea-molasses supplementation are shown in Fig. 4.1, 4.2 and 4.3 respectively. The degradation characteristic are also shown in Table 4.1.

The soluble fractions were highest in ammoniated straw (AS) for all the nutrients than the other diets. The potential degradable fraction in DM and NDF were highest in urea-molasses supplemented diet (UMBS) while that of N showed the highest value with AS. Observations made with the rate of nutrient degradation were similar to that of potential degradable fractions (Table 4.1).

Fig. 4.1. Effect of Urea ammoniation (AS) and Urea-Molasses Block Supplementation (UMBS) on Dry Matter (DM) disappearance in Rice Straw incubated in the rumen of sheep

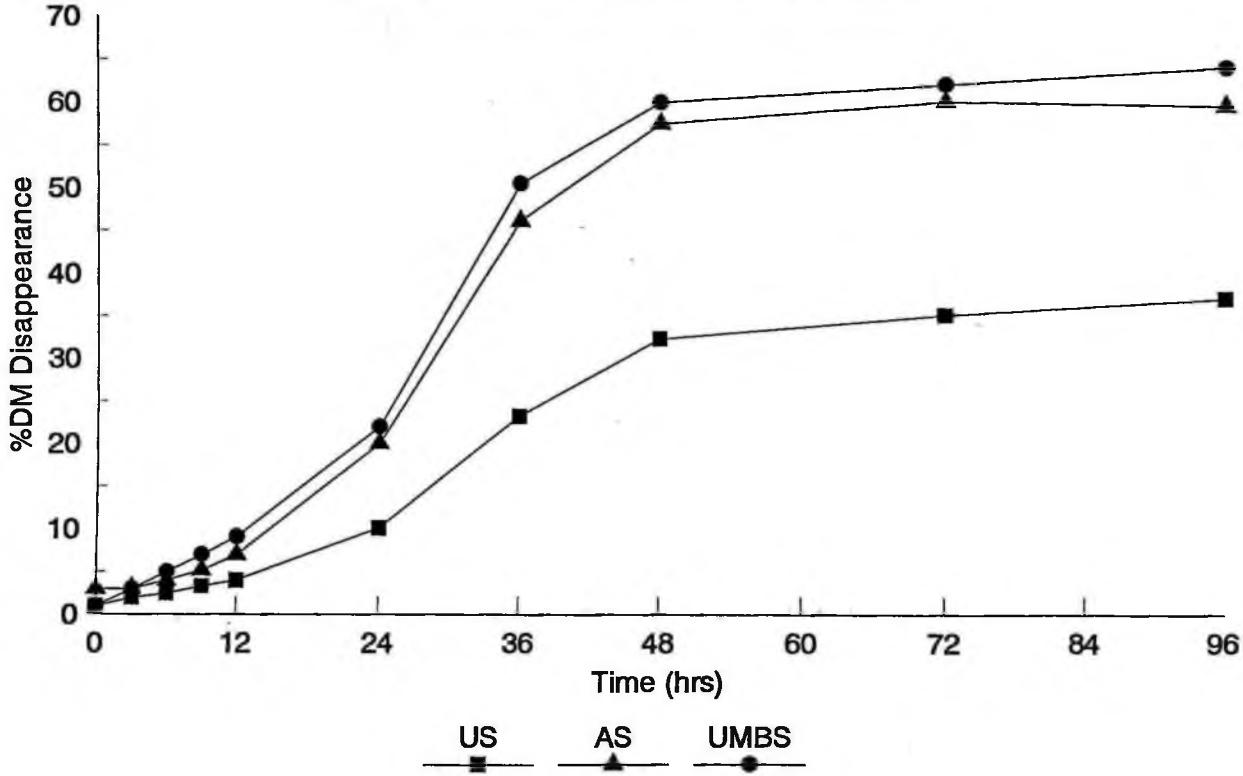


Fig. 4.2. Effect of Urea ammoniation (AS) and Urea-Molasses Block Supplementation (UMBS) on Neutral Detergent Fibre (NDF) disappearance in Rice Straw incubated in the rumen of sheep

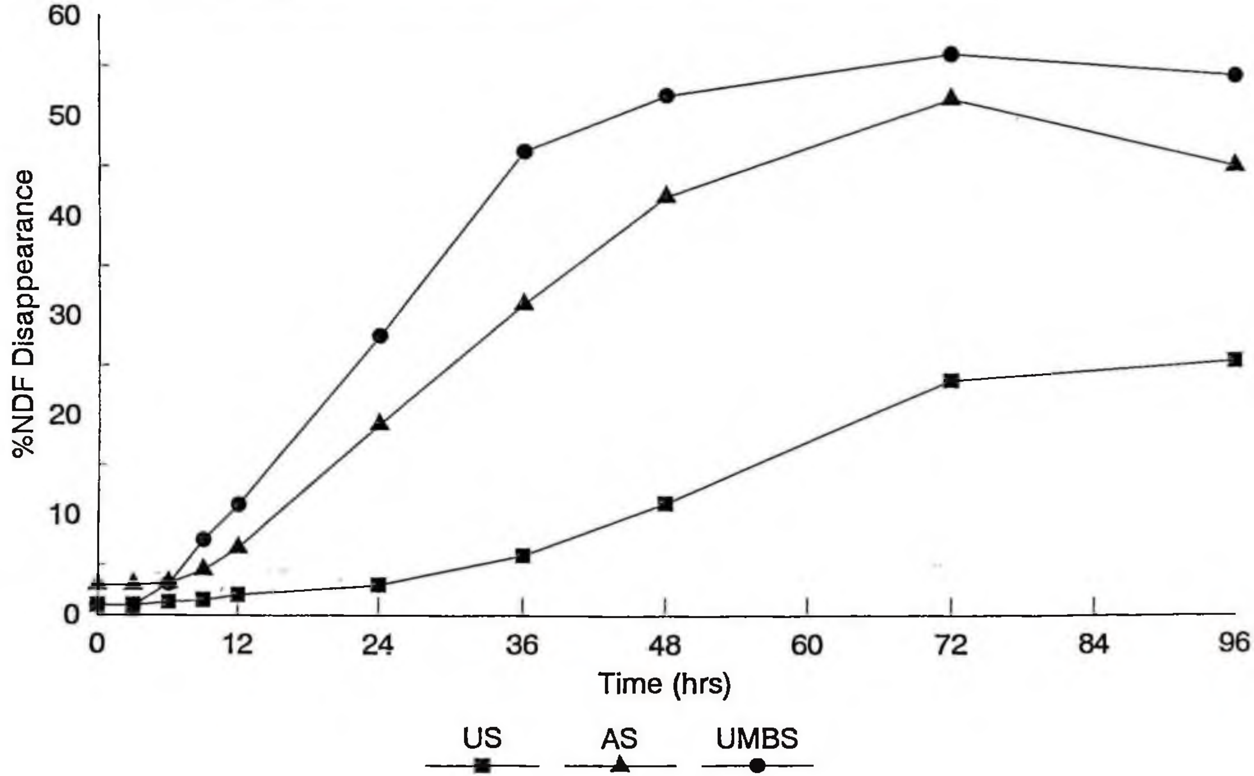


Fig. 4.3. Effect of Urea ammoniation (AS) and Urea-Molasses Block Supplementation (UMBS) on Nitrogen disappearance in Rice Straw incubated in the rumen of sheep

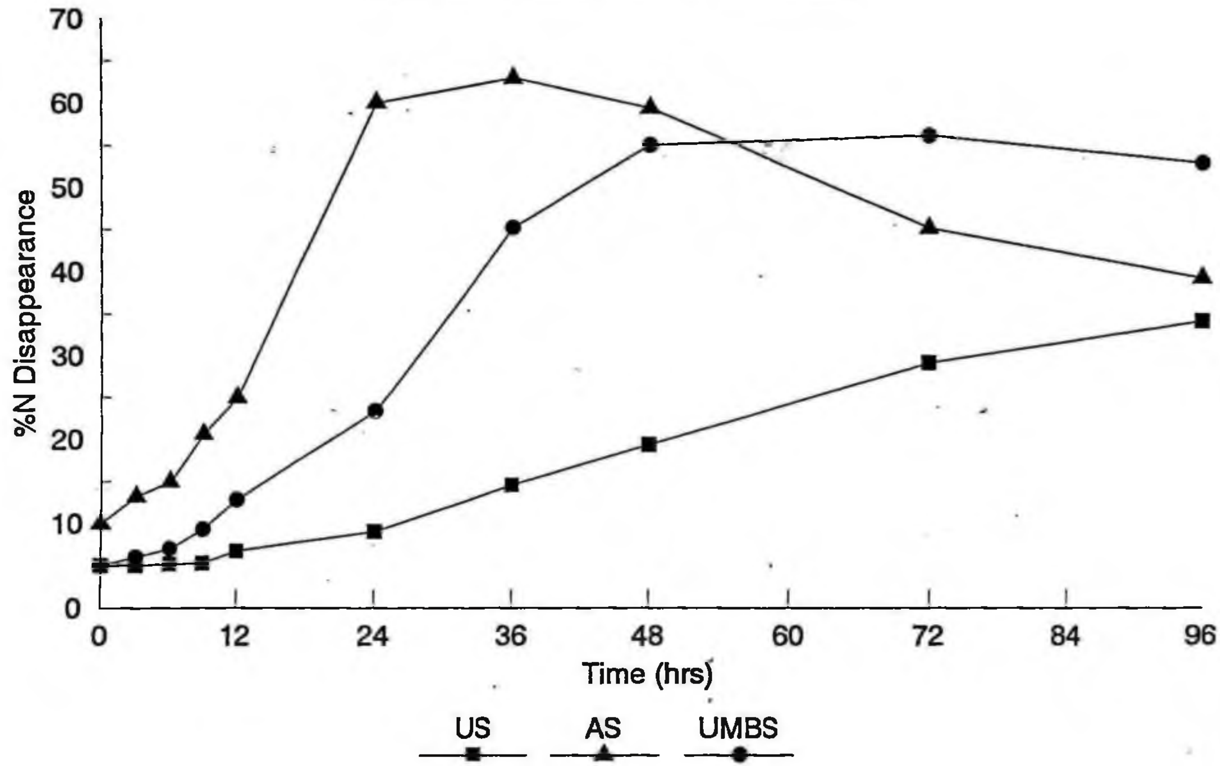


Table 4.1: **Effect of dietary treatment on rumen degradation characteristics of DM, NDF and N in sheep fed low quality roughage.**

Nutrients	Diet								
	Untreated Rice Straw			Ammoniated Rice Straw			Urea-molasses supplemented Rice Straw		
	a	b	c	a	b	c	a	b	c
DM	1.0	35.0	0.018	3.0	57.0	0.025	1.0	62.0	0.027
NDF	1.0	25.0	0.016	3.0	49.0	0.021	1.0	55.0	0.027
N	5.0	30.0	0.010	10.0	55.0	0.044	5.0	51.5	0.026

a = Solubility (%)

b = Degradable fraction (%)

c = The rate constant for the degradation of 'b' (h^{-1}).

4.3.2 Rumen ammonia and pH

Ruminal fluid ammonia and pH changes with time are shown on Figures 4.4 and 4.5 respectively.

Rumen ammonia concentration doubled with urea-molasses supplemented diet. The concentration rose from 11.13 mg/100ml at the time of feeding to 24.07 mg/100ml 24 hours after feeding. Ammoniated diet showed an increase from 8.32mg/100ml at time zero to 17.64mg/100ml 8 hours after feeding and then dropped to 11.88mg/100ml at 27 hours. The concentration decreased from 9.93 to 7.96mg/100ml with the untreated diet.

The pH of ruminal fluid decreased from 7.16 at time zero to 6.04 24 hours later when sheep were fed urea-molasses diet. Ammoniated diet showed slight fall in pH. (i.e from 7.38 to 6.70 after 24 hours). On the contrary untreated straw showed an increase from 7.17 at the time of feeding to 7.42 at 24 hours.

Fig. 4.4 Effect of dietary treatment on rumen ammonia concentration of sheep sampled 4 hours before feeding, at feeding and 4 hourly interval after feeding

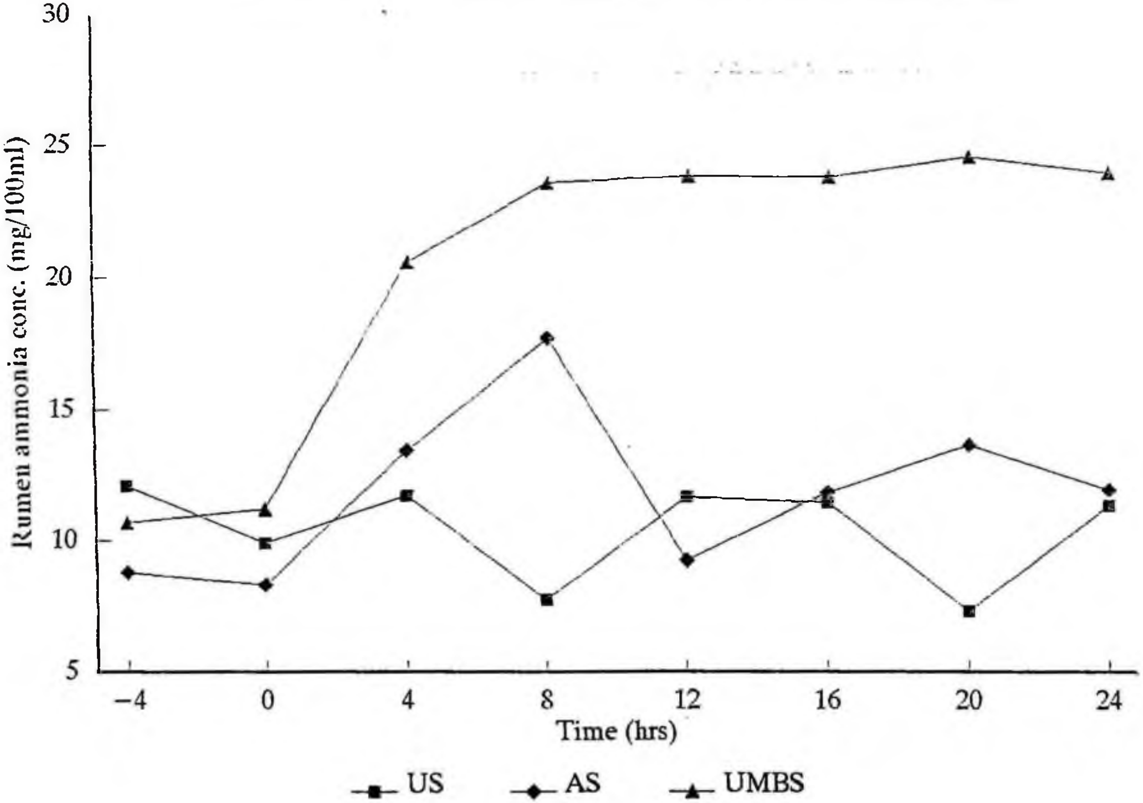
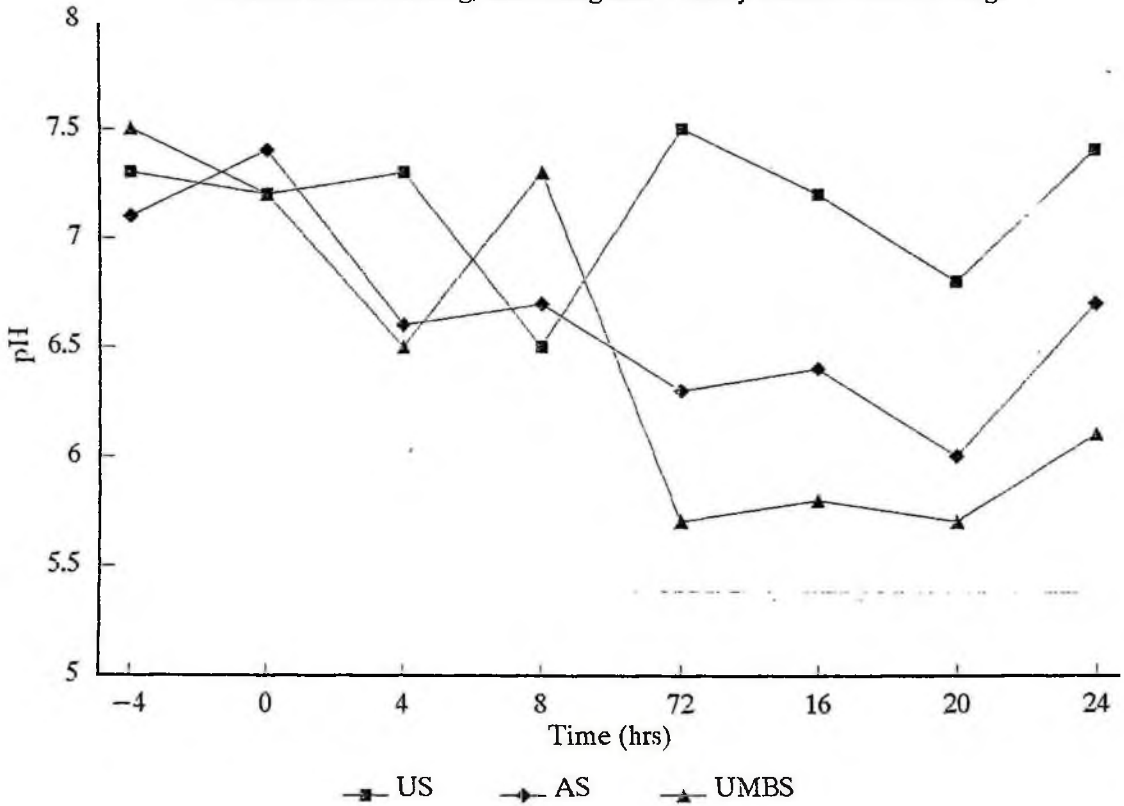


Fig. 4.5 Effect of dietary treatment on rumen pH of sheep sampled 4 hours before feeding, at feeding and 4 hourly interval after feeding.



4.4 DISCUSSION

4.4.1 Rumen Degradation

The higher solubility of DM, NDF and N in ammoniated straw compared to the other two diets could be explained by the fact that ammoniation caused solubilisation to some extent of the fibrous fractions of the straw as reported by (Solaiman *et al.*, 1979). Untreated fibrous materials have been found to be less soluble because of the dominance of lignin which is chemically bound to structural carbohydrates in the cell wall (Van Soest, 1982).

The higher degradable fraction of DM and NDF in both the urea-molasses supplemented and ammoniated diets compared to the control was due to the available energy (molasses in the block and structural carbohydrate in the ammoniated straw) and non-protein nitrogen (urea) which facilitated the rumen microbial action on the straws. Accordingly, there was little difference in the rate of DM degradation between the two test diets (Table 4.1). The difference in the rate of NDF was however quite large (0.027 for urea-molasses diet and 0.021 for ammoniated diet). This latter observation seems to highlight the need for both readily fermentable nitrogen and carbohydrate when it comes to the break down of cell wall constituents (Preston and Leng, 1984). Further explanation could be that, the sulphur supplied by the molasses also enhanced the activities of rumen microbes which culminated in increased rate of structural breakdown.

In general, the extent of N degradation increased with time for all the diets during initial hours of incubation (Fig. 4.3). The ammoniated straw showed a sharp fall in N disappearance after 36 hours whilst urea-molasses maintained constant disappearance up to 72 hours. The untreated diet kept increasing in degradation until 96 hours. The sharp fall in N disappearance in the ammoniated diet seems to indicate that some ruminal bacterial had adhered to roughage particles and were not removed by washing and rinsing. In the case of the urea-molasses block supplemented diets rumen microbes were not vigorous in adhering to the raw straw. Janicki and Stallings (1988) observed that adhesion of microbes to urea treated orchard grass during incubation resulted in higher N content of the ammoniated hay 2 hrs after incubation compared to that at the beginning of the incubation. Several researchers (Kennedy, Hazelwood and Milligan, 1984; Nocek, 1988; Nocek and Grant 1987) have also demonstrated that bacterial contamination of ammoniated straws increase with time of rumen incubation.

4.4.2 Rumen ammonia and pH

The increase in the ammonia concentration with the ammoniated diet from time of feeding to 8 hours after feeding was due to rumen microbial attack liberating ammonia into the rumen pool. The fall from then on could be due to the utilisation of the ammonia by the microbes (Satter and Slyter, 1974) and absorption through the rumen epithelium into the portal blood (Bloomfield, Kearley, Creach and Muhrer, 1963).

The elevation in the ammonia concentration in ruminal fluid when diet was supplemented with urea-molasses (Fig. 4.4) probably was not the result of lesser utilisation of ammonia by bacteria as suggested by McCarthy *et al.*, (1989). This is because microbial action associated with this supplement was substantially high especially with DM and NDF degradation (Fig 4.1 and 4.2). The elevation was therefore probably due to a decreased absorption rate of ammonia through the ruminal epithelium because of the acidic nature of the ruminal fluid. The pH values were consistently lower with the urea-molasses supplement than the other diets (Fig. 4.5). The effect of pH on ammonia absorption has been demonstrated by Horgan (1961) and Bloomfield *et al.*, (1963). Bloomfield *et al.*, (1963) reported that when rumen pH was 7.55 and 6.21, ammonia absorption was 26 and 11 mmol/l/h respectively. Horgan (1961) also found that at a pH of 6.5 the transport of ammonia across the rumen epithelium was rapid, but tended to be negligible at pH 4.5. The optimum concentration of ammonia-nitrogen for maximal rumen fermentation was estimated as 17-23 mg/100ml (Merez *et al.*,1977). This implies that with low quality feed such as rice straw, low concentration of ammonia could limit microbial action in the rumen. This limitation is however averted with some fortification. Supplementation with urea-molasses block and ammoniation with urea have shown in the present work to have the ability to improve upon the rumen ammonia concentration for microbial growth and fermentation in sheep fed rice straw.

The results show that urea ammoniation and urea molasses block supplementation increase both rate and extent of degradation in addition to maintaining favourable rumen environment for efficient fermentation.

CHAPTER FIVE

EXPERIMENT 3

5.0 TITLE: Effect of substituting wheat flour with gari and kokonte flour on the feeding value of urea-molasses block.

5.1 INTRODUCTION

Observations from the previous experiments suggest that the feeding of readily fermentable energy source together with urea enhanced intake, degradation and utilisation of untreated rice straw. Preston and Leng (1984) suggested that, for nutritional supplements on straw-based diet, the top on the priority list is the provision of readily-fermentable carbohydrates. The next is the provision of a source of fermentable nitrogen followed by the supply of energy.

The present study compared the use of cassava products (gari and konkote flour) with wheat flour as sources of dietary energy in the urea-molasses block.

5.2 MATERIALS AND METHODS

5.2.1 Animals

The study consisted of two parts. The first part invoved the use of three fistulated and three "intact sheep" to study the consumption of the urea molasses blocks and rumen parameters, including rumen degradation of the blocks.

In the second part nine animals were used for growth response studies. All the animals were initially treated to control helminths and ectoparasite with standard medication similar to those used in the previous experiments.

5.2.2 Diets

Untreated rice straw supplemented with urea-molasses blocks were fed to the experimental animals. The blocks containing the three energy sources were :

1. Wheat flour (WB)
2. Gari (GB)
3. Kokonte flour (KB)

Gari and kokonte flour were traditionally processed as described by Dovlo (1972), Laryae-Brown and Anderson (1980) and Food Research Institute (1984).

Management of animals was as described in Experiments One and Two.

5.2.3 Experimental Design

5.2.3.1. Intake and Rumen Studies

The paired groups of fistulated and 'intact' animals were assigned to the three treatments in order to form a two 3 x 3 latin square design. The fistulated animals were used for rumen studies. The animals were fed *ad libitum*. They were fed once a day. There were three periods of seventeen days duration for each treatment. The first ten days were for acclimatization of animals to supplements and the next seven days for data collection of which the final two days were used for nylon bag and rumen pH studies. Quantities of straw and urea-molasses block consumed were recorded daily.

5.2.3.2 Growth Trial

Nine wethers (average age: 8 months) were randomly assigned to the three treatments with three animals per treatment in a randomized complete block design. The animals were weighed before the commencement of the experiment and then fortnightly for fifty-six days.

5.2.4 Statistical Analysis

The data were analyzed by analysis of variance and treatment means compared by the method of Student-Newman-Keul's test.

5.3 RESULTS

Table 5.1 shows the ingredient, composition, crude protein (CP) content and calculated metabolizable energy (ME)[1] content of the experimental blocks.

Table 5.2 shows the proximate chemical composition of the experimental blocks. The striking feature is the crude fibre levels. GB gave the highest fibre content of 340 g/kg, 40g more than WB and 70g more than KB.

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[1] ME = Sum total of ME of various ingredient of the experimental blocks as given by Grampton and Harris (1969) and Dovlo (1972).

Table 5.1: **Ingredient composition, Crude Protein (CP) and calculated Metabolizable Energy (ME) contents of experimental blocks***

Ingredients	Block Composition (g/kg)		
	WB	GB	KB
Molasses	400	400	400
Wheat flour	100		-
Gari		100	
Kokonte			100
Copra cake	120	120	120
Wheat bran	200	200	200
Cement	80	80	80
Urea	60	60	60
Common salt	40	40	40
Calculated ME (MJ/kg)	10.0	9.82	10.1
CP (g/kg)	271	254	257

*WB, Block containing wheat flour; GB, Block containing Gari; KB Block containing Kokonte.

Table 5.2: **Proximate chemical composition of urea-molasses blocks of different energy sourcses**

Energy Sources in Block	Composition (g/kg)			
	DM	CP	OM	CF
Wheat Flour (WB)	897	280	804	300
Gari (GB)	906	270	814	340
Kokonte (KB)	913	262	810	270

Average dry matter intake of both the experimental blocks and the untreated straw are given in Table 5.3. Consumption of GB was significantly ($P<0.05$) greater than the other two blocks (KB and WB). This was associated with significantly ($P<0.05$) higher intake of straw and total dry matter by animals consuming GB than those on KB and WB. The difference in intake of block dry matter between WB and KB was 6.3% but statistically not significant ($P>0.05$).

Total dry matter intake on the three blocks appeared to relate the crude fibre content of the blocks. Total crude protein intake followed the same pattern as the dry matter intakes (Table 5.2).

Table 5.3: Dry matter (DM) and Crude protein (CP) intakes by sheep fed rice straw supplemented with urea-molasses block of different energy sources during the nylon bag studies.

Intake	Energy Sources			
(DM kg/d)	Flour (WB)	Gari (GB)	Kokonte (KB)	SE.(df)
Block	0.47^{A}	0.81^{B}	0.50^{A}	23.09 (15)
Straw	0.54^{A}	0.78^{B}	0.47^{C}	14.62 (15)
TOTAL DMI	1.01^{A}	1.59^{B}	0.97^{A}	0.034 (15)
TOTAL CPI	0.16^{A}	0.25^{B}	0.15^{A}	0.013 (15)

Note: Means in the same row with different superscripts are significantly different ($P<0.05$).

The extent of ruminal degradation of the blocks is shown in Fig.5.1. The block containing "kokonte" was most soluble as well as most potentially degradable. The degradable fraction figures for WB, GB, and KB were 62.1, 52.1 and 50.5 respectively (Table 5.4). The table also indicates that the degradation rate of the blocks was most rapid in KB followed by WB.

Figure 5.2 shows the rumen pH pattern of sheep fed the three different types of blocks. At the time of feeding the pH of all groups was between 7 and 8. They however, progressively declined to between 4 and 7 within a period of 24 hours. The decline was highest with KB which fell from pH of about 8 to about 4. Animals on GB had the most steady pH declining from around 7 to about 6.8.

Table 5.5 shows the mean liveweight gains and feed conversion ratio of sheep fed the experimental blocks. The average daily gain was significantly ($P<0.05$) highest in animals supplemented with GB (80.3g/d). Animals of the GB block utilized their feed most efficiently ($P<0.05$). Differences between KB and WB with respect to total dry matter intakes and feed conversion ratio were not significant ($P>0.05$).

Fig. 5.1 The pattern of disappearance of Urea–Molasses Block of different energy sources incubated in the rumen of sheep

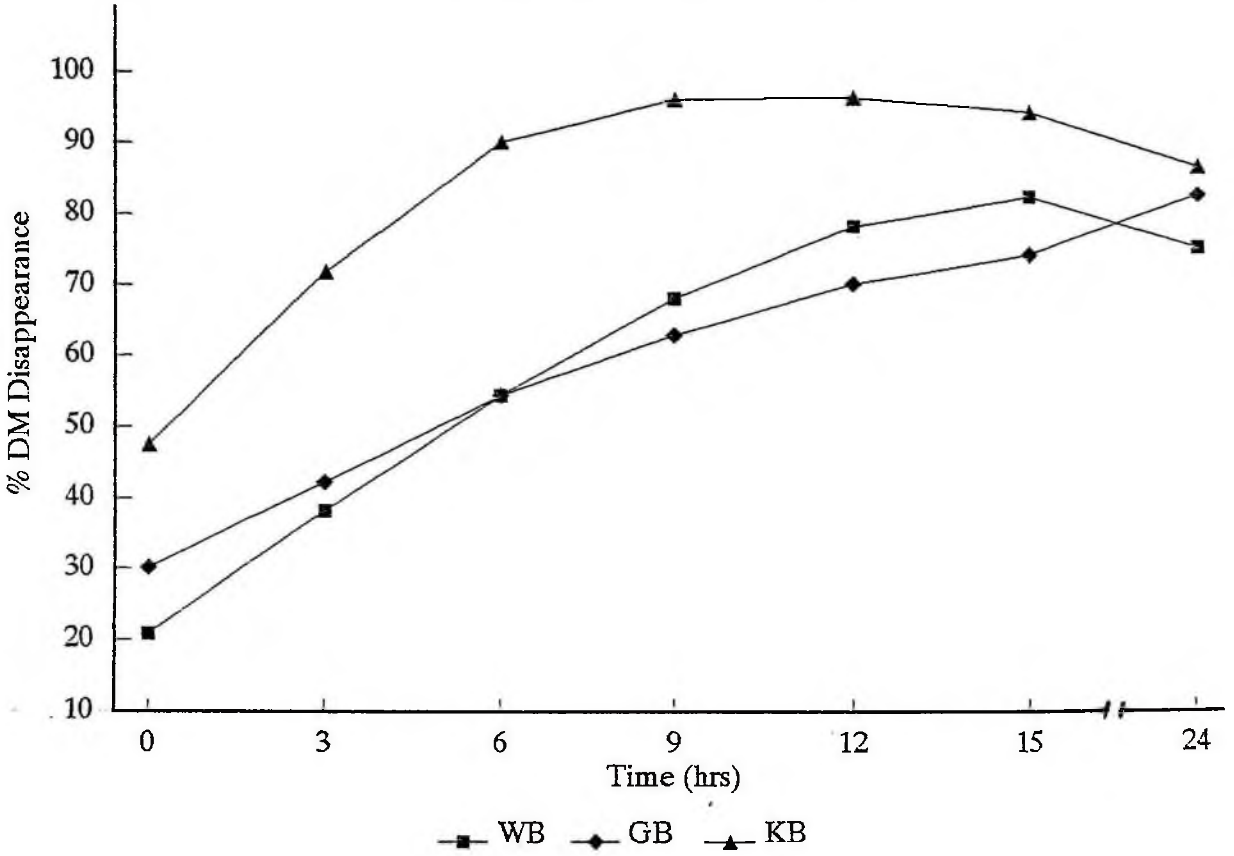

Fig.5.2 Effect of type of Urea–Molasses Block on ruminal pH of sheep fed blocks containing different energy sources

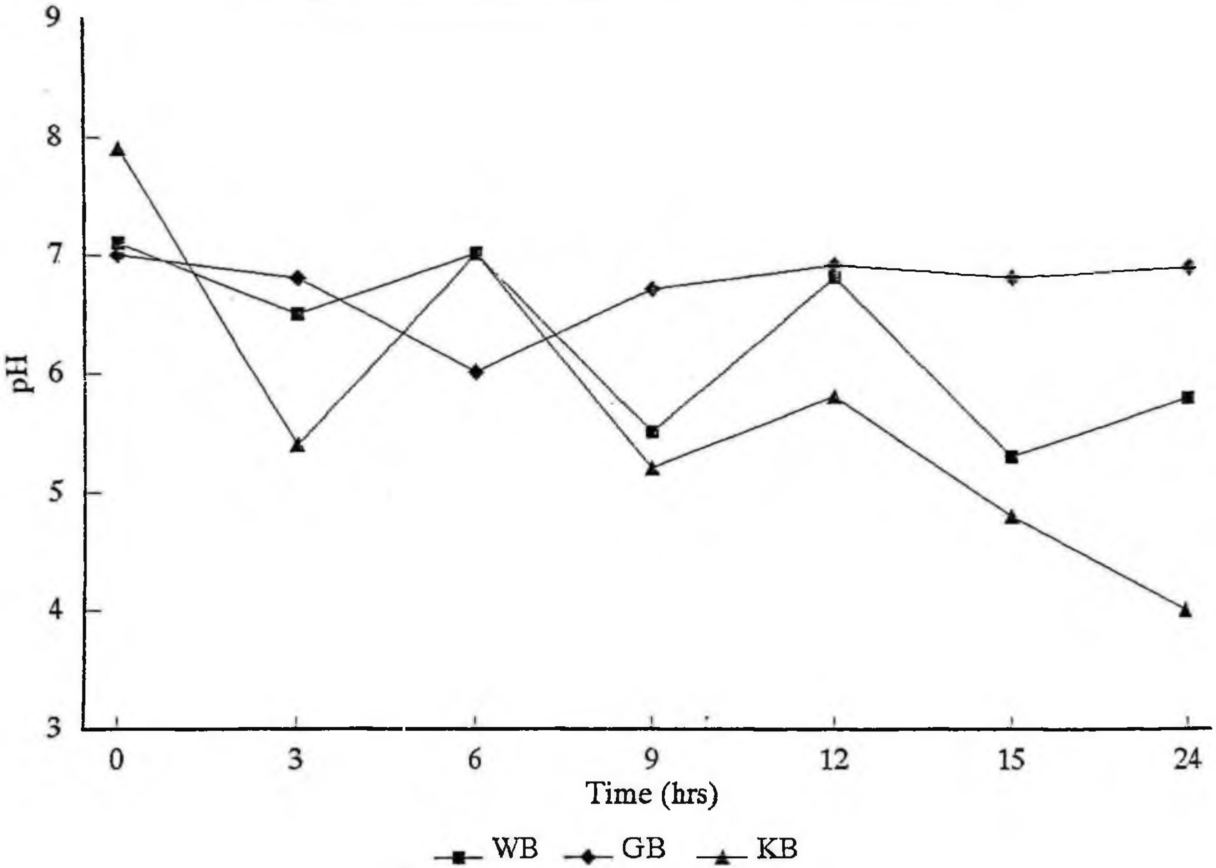

Table 5.4: Degradation characteristics of urea-molasses blocks of different energy sources incubated in nylon bags in the rumen of sheep.

Energy Source	Soluble (a)	Degradable Fraction (b)	Rate of Degradation (c)	Undegradable [100-(a+b)]
Weat Flour (WB)	20.9	61.2	0.13	17.9
Gari (GB)	30.3	52.1	0.10	17.6
Kokonte (KB)	47.5	50.5	0.22	2.0

Table 5.5 Average dry matter intake and mean liveweight gains of sheep fed rice straw supplemented with urea-molasses block of different energy sources during the growth trial.

	Block Components			
	Flour (WB)	Gari (GB)	Kokonte (KB)	S.E. (6 d.f.)
Total DMI (g/d)	961^{A}	1529^{B}	949^{A}	44.006
Initial liveweight (kg)	20.0^{A}	18.0^{B}	19.2^{AB}	0.378
Final liveweight (kg)	23.0^{A}	22.5^{A}	21.5^{A}	0.577
Average daily gain (g/d)	53.6^{A}	80.3^{B}	41.0^{A}	9.857
Feed Conversion ratio (kg DMI/kg wt. gain)	18.1^{A}	17.3^{B}	23.2^{A}	3.553

Note: Means in the same row with different superscripts are significantly different ($P<0.05$).

5.4 DISCUSSION

Supplementation with GB resulted in the highest straw and urea-molasses block intake indicating that the GB appeared to stimulate rumen microbial action more than either KB or WB. These results support the hypothesis of Van Soest (1982) that the higher fibre component of the GB (Table 5.2) served to buffer the rumen pH to the optimum level of 6.5-6.9 (Fig. 5.2). According to Van Soest (1982) and McBurney *et al.* (1986), fibres encourage buffering through increased salivation and cation exchange. They further reported that the cation exchange improves mineral metabolism in ruminant nutrition hence, the invigorating effect of the GB supplement on total dry matter intake (DMI) (Table 5.3).

Even though GB showed the lowest energy content (Table 5.1), the higher DMI probably provided daily 7.95 MJ metabolizable energy (ME) and was far more than the maintenance requirement of the 20 kg wethers which is 3.8 MJ ME (MAFF, 1975 and SAC, 1978). The intakes of KB and WB gave 5.05 and 4.70 MJ ME consumption respectively.

The slower degradation rate of GB (Table 5.4) also indicated that a portion may have passed more rapidly through the rumen and into the lower tracts to meet the direct requirement of the animals. The high solubility of KB coupled with high rate of degradation could have contributed to the rapid decline in rumen pH associated with animals fed KB supplemented diet throughout the experiment (Fig.5.2). Many workers have associated lower rumen pH with low straw intake and digestion (Mould *et al*, 1983; Van Soest, 1982).

The average weight gain and feed conversion efficiency in sheep fed GB supplemented straw were accordingly, significantly higher than sheep fed KB and WB diets. KB showed the least values and appears to be the least in terms of feeding value as compared to GB and WB (Table 5.5).

In conclusion, the study has shown that to provide sufficient energy and maintain favourable rumen environment in sheep offered rice straw, gari contained urea-molasses block would be a better supplement than kokonte or wheat flour contained blocks.

CHAPTER SIX

6.0 GENERAL DISCUSSION

The parameters used in evaluating the nutritive value of untreated straw (US), urea ammoniated straw (AS) and urea-molasses block supplemented straw (UMBS) were dry matter intake (DMI), nutrient digestibility, rumen degradation and the ability to prevent dry season weight loss.

The DMI of AS and UMBS were both higher ($P<0.05$) than untreated straw (Chapter 3). The higher intake found with AS has been attributed to a number of factors including solubilisation of hemicellulose and by exposure of more surface area for microbial action (Zorrilla-Riose *et al.*, 1984). The appreciable intake observed when straw was supplemented with urea-molasses block is attributed to the availability of nitrogen in urea and sulphur (Amaning-Kwarteng, 1986) and fermentable carbohydrate in the molasses (Nuwanyakpa and Butterworth, 1987). Sulphur plays an important role in ruminant digestion especially in sheep (Bird, 1973; Kennedy and Siebert; 1973 and Akin and Horgan, 1983). Akin and Horgan (1983) found that sulphur stimulated rumen fungi which caused fibre degradation by attacking and weakening lignocellulose tissue in the rumen resulting in less retention time of the straw.

Apart from OM all other nutrients were observed with higher digestibility coefficients when AS was fed than UMBS Low crude protein digestibility associated with UMBS is attributed to high intake of nitrogen due to the high crude protein content of the block. The lower NDF digestibility with UMBS (Chapter 3) have also been attributed to the slight decline in rumen pH (Mould *et al.*, 1983).

In Chapter four, studies on rumen degradation shows that the extent and rate of fibre (NDF) and DM degradation were higher with UMBS than AS and US. This observation between UMBS and AS is directly opposite to the digestibility values obtained from *in vivo* studies in Chapter three. This suggests that more AS was further digested down the digestive tracts (i.e. Abomasum and Intestines) than UMBS. It is therefore reasonable to assume that the beneficial effect of the urea-molasses block resulting in higher fibre degradation is more in the rumen than in the lower tracts.

The formula proposed by MAFF (1975) was used as an indicator of the experimental diets to meet maintenance requirements. AS and UMBS could provide the required maintenance energy and even provide for growth (Table 3.4 and 3.5). AS and UMBS could therefore be used as basal diets where there is a need to turn over animals for marketing. Appropriate supplementation would have to be made before the US could be used for productive purposes, otherwise it may be just adequate in maintaining animals during the lean seasons.

The need for utilising local feedstuffs to solve the feeding problem necessitated the study carried out in Chapter five. The potential shown by the urea-molasses combination in chapters three and four could be an illusion especially to our local farmers if the original formula is maintained. This is because some of the components are not readily available or affordable. Gari or Kokonte were therefore used in place of wheat flour as source of dietary energy in the block and their feeding value evaluated. The high crude fibre content experienced with gari contained block (GB) is believed to cause a marked improvement in the intake of both block and straw. According to Van Soest (1982), the high fibre content in GB stabilised the rumen environment due to its buffering capacity. The slower degradation rate of GB rendered gari the best rumen "by-pass" energy source as compared with kokonte and wheat flour. Addition of GB therefore increased the amount of energy available for digestion in the intestines, more than KB and WB. The availability of energy in the lower tracts has been observed to be very important in ruminants, (Preston and Leng, 1984). Accordingly, GB recorded the best feed conversion efficiency which even resulted in a body growth rate higher than these with both AS and UMBS observed in Chapter three.

CHAPTER SEVEN

7.0 CONCLUSION

The abundant straws being produced in the country represent a significant proportion of the feed resources available to majority of small holder producers. However, their low and slow digestibility indicates that they can, at best, be used only to support maintenance requirement during the dry season.

Improvements in feeding value of straws through urea ammoniation and urea-molasses block supplementation have been achieved in this work with respect to intake, digestibility and growth responses. However, in view of the great potential of urea-molasses combination, and for the fact that some of the constituents are not readily affordable, the author recommends that further work should be done to assess the usefulness of locally available materials in replacing the rather more expensive components of the blocks. Experiment three had shown that gari for example could be a better substitute for wheat flour as a energy in the urea-molasses block.