STUDIES ON VARIOUS TREATMENT CONDITIONS AFFECTING UREA-AMMONIATED RICE STRAW IN GHANA

BY

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A thesis submitted in partial fulfilment of the requirements for the Degree of Master of Philosophy

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June 1992

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DEDICATION

This work is dedicated to

my husband, Peter and

my son Sesi.

DECLARATION

This dissertation is the result of my own research work and it 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. References cited have, however, been fully acknowledged.

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ACKNOWLEDGEMENTS

I am sincerely grateful to Rev. Dr. Kofi Amaning-Kwarteng, Dr. J.E. Fleischer and Dr. F. Fianu, my supervisor and co-supervisors respectively for their never failing support, unlimited guidance and encouragement, constructive criticisms and immense assistance in the course of this study.

My deep appreciation and sincere thanks are extended to the following for the immense help and special interest they showed during this project. Dr. E.A. Canocoo, Dr. B. Awumbila, Miss G. Aboagye, Professor R.K.G. Assoku, Dr. G.E.S. Williams and Mr. & Mrs. K. Offei.

I wish to acknowledge my indebtedness to: Mr. Kwartey Quartey and Mr. David Mensah for their skilled, resourceful and patient management of experimental animals; Mr. Abubakari Yakubu for valuable and excellent technical assistance; Mr. Kwarteng and Mr. T. Amedzekey for valuable assistance in statistical analysis, Mr. O. Debrah, Mr. S.K. Ottoo, Mr. Enoch Laryea, Mr. Kwei Mensah and Mr. Josef Grinner for their helpful assistance at the Agricultural Research Station, Legon.

I am also grateful to Mr. Maxwell Odonkor, Mr. E.T. Obodai and Mrs. Lynda Anyomi. Without their assistance this work would have been more difficult.

I am greatly indebted to Mrs. Faustina Korsah for assisting in typing and printing out the thesis.

My sincere thanks and appreciation are extended to my colleagues Messrs G. Banini, E. Otu, Tackie, Seth Akah, A. Tei-Mumu and Boateng for their useful and valuable discussions, company at all times.

I would like to express my deep appreciation, sincere gratitude and unlimited indebtedness to my husband Peter Tamakloe, my sisters Sika, Cherie and Aimee, my brother Andy and my parents for their understanding, encouragement, patience and prayer support during the course of this study.

Finally, I ascribe to the Lord Jesus the glory, honour, and praise due His Name. Without His enablement, it would have been impossible to begin and complete this study.

ABSTRACT

Four experiments were undertaken to evaluate the effect of various treatment conditions on the nutritive value of urea-ammoniated rice straw.

Experiment 1 was carried out to determine the optimum condtions necessary for ammoniating rice straw with urea. The factors investigated included urea concentration (3.5, 4.0, 6.5 and 8.0% w/w), treatment period (7, 14 and 21 days) and moisture level (40, 50 and 60%), in a 4 x 3 x 3 factorial experiment.

Samples were analysed for total Nitrogen content, neutral detergent fibre (NDF), acid detergent fibre (ADF) and *in vitro* organic matter digestibility (IVOMD). Results showed that the optimum urea concentration, treatment period and moisture level were 6.5%, 21 days and 40% respectively.

In Experiment 2, the optimum conditions obtained in Experiment 1 were used to treat rice straw which was then stored in different types of silo (earthern pit, cane basket and cement culvert) to determine the best silo to use. The earthern pit was found to be the best among the silos with its contents having a N content of 1.75% and IVOMD 52.65. Straw from the basket and culvert had 1.55% and 1.10% N and 50.03 and 48.21 IVOMD respectively.

The *in situ* rate of ruminal dry matter (DM) disappearance (DMD) (3-72h) and extent of DM disappearance (72h) investigated in Experiment 3 indicated that urea

ammoniated straw was more fermentable in the rumen of sheep compared with untreated rice straw. The rate and extent of DMD was found to be 0.48%/hr and 44.64% for untreated rice straw and 0.74%/hr and 58.97% for ammoniated rice straw.

Urea treatment significantly increased straw intake but did not prevent sheep weight loss in Experiment 4.

Straw ensiled with urea for 21d and fed to sheep with little supplementation can supply maintenance needs of ruminants during the dry season.

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CHAPTER 1

1.0 INTRODUCTION

The main feed resource for ruminants in Ghana is the natural grassland. Rose-Innes and Mabey (1964) and Fianu, Atta-Krah and Koram (1972) have indicated that crude protein contents of Ghanaian grasses, in general, ranged from 5 to 13% in the rainy season, but fell to about 3% in the dry season. Consequently, ruminant animals gain weight during the wet season but lose weight in the dry season. In the face of this feed resource inadequacy, increasing but effective use of crop residues in feeding ruminant livestock is a good alternative since about 6 million metric tonnes of residues are produced yearly (Fleischer, unpublished).

Crop residues are, however, known to have low nitrogen content and low digestibility. Consequently, they have a low animal production potential. Rice straw, for instance, contains about 80% potentially digestible substances and is therefore a source of energy. However, its actual digestibility by ruminants is only 45-50%. Furthermore, the amount the animal 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).

Most of the work done on low quality roughages reveals that physical and/or chemical treatments with or without supplementation (with energy, protein and mineral) improve the utilization of these feedstuffs of ruminants.

The upgrading of low quality roughages by means of ammonia treatment has been reviewed by Sundstol, Coxworth and Mowat (1978). An indirect method of ammoniation of crop residues has also been reported by Jayasuriya & Perera (1982) and Nour (1986). This treatment depends on the enzymatic release of ammonia from urea (or other non-protein sources of ammonia e.g. biuret added to the roughage) in an aqueous medium.

Research results have proved ammoniation by urea to be effective in improving the in vitro organic matter digestibility (IVOMD), voluntary intake and in vivo digestibility of wheat straw (Kritzinger and Franck 1981; Cloete, De Villiers and Kritzinger, 1983). This method of ammoniation appears to be relatively safe, uncomplicated and inexpensive when compared to sodium hydroxide treatment and anhydrous ammonia treatment.

Success with urea ammoniation however, depends strongly on the effectiveness of ureolysis which in turn is related to urease activity in the material, moisture level of the material, environmental temperature, urea level and length of treatment. (Guessous, et al, 1989). Little work has been done in Ghana to elucidate the treatment conditions that affect the urea ammoniation of straw.

The objective of this study is therefore to evaluate the factors that influence the effective ammoniation of straw under Ghanaian conditions using urea as the source of ammonia. The factors are: treatment period, urea concentration and moisture content of straw.

The effect of type of silo (earthern pit, cane basket or cement culvert) on the nutritive value of treated straw will also be determined and a preliminary study on the potential of the ammoniated straw as a dry-season feeding material embarked upon.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The major crops grown in Ghana and which provide residues of potential value for ruminants are shown in Table 2.1.

The residues produced at harvest or during the farm processing of the crops, (stovers, straws, haulms, vines, leaves, peels) are not being maximally utilized because of a number of constraints.

One of the major constraints is the generally low nutritive value of these crop residues. They have low nitrogen, high fibre contents and are poorly digested such that they barely meet the maintenance requirements of livestock (Sundstol, Coxworth and Mowat, 1978). They need to be upgraded by treatment or appropriate supplementation in order to exploit fully the role they could play in ruminant nutrition.

The factors that influence the intake and utilization of crop residues and the various treatments adopted to improve their nutritive value are reviewed.

2.2 NATURE AND QUALITY OF AVAILABLE FEED RESOURCES

2.2.1 Crop Residues and Agro Industrial By-Products

Crop residues are defined by Smith (1987) as the material left after harvesting the crops (maize stover, cassava tops, maize cobs, cassava peels, rice straw). These materials are usually high in fibre, low in nitrogen and are widely distributed in the farming communities of Ghana. Crop residues usually constitute the available feeding material during the dry season.

Table 2.1: Some nutritionally important crop residues and agro-industrial by-products produced in Ghana

Crop	Residue	By-Product
Maize	Stover Cob	Bran Husk
Rice	Stubble Straw	Bran Husks Rice mill feed
Sorghum	Stover	'Bran'
Wheat (imported)	-	Bran
Groundnut	Haulms Husks	Groundnut cake
Cowpea	Vines & Pods	
Cocoa	Pods	Shells
Cotton		Cotton seed cake
Coconut	Husk	Copra cake
Oil Palm		Palm pressed fibre Palm kernal cake
Plantain and Banana	Leaves Psudostems Peels & rejects	
Sugarcane	Tops	Molasses Cane juice Bagasse
Cassava	Peels & rejects Tops (leaves)	Starch
Sweet Potatoes	Vines and Peels	
Pineapples and citrus fruits	Tops	Pulp

Agro-industrial-by-products, on the other hand, are produced mainly after processing the crops and could be physically and nutritionally different from the starting crop. They could be rich in nitrogen and low in fibre (eg. oil seed cakes, some brewery and flour milling by-products) or low in nitrogen and high in fibre (eg. sugarcane bagasse, palm press fibre). A few like palm kernal cake are high in both nitrogen and fibre. Since they are produced at factory sites, they are less widespread in location. These agro-industrial-by-products are generally used as supplements to low quality forages for ruminants and therefore not used as basal feeds.

2.2.2 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 growth rate. Crop residues are bulky and are unfortunately available mainly in areas with low animal population density. The cost of transportation from production sites to livestock areas may be so high, that farmers are forced to just burn these residues as a means of disposal on the farms. There is a need to educate farmers on the means of improving the feeding value of crop residues and the usefulness in feeding them to animals.

2.3 POTENTIAL FEED VALUE OF CROP RESIDUES

2.3.1 Intake of Crop Residues

In studies in which crop residues were fed as the sole or major material, intake and digestibilities of the diet were found to be very low. Cheva-Isarakul and Cheva-Isarakul (1985) fed adult wethers, weighing about 30kg, five different varieties of rice straw ad libitum to estimate voluntary intake and digestibility. On the average the sheep consumed about 2.2 percent of their body weight or 52 g/kg metabolic weight of the straw. Dry matter digestibility was 49.8%. Suriyajantratong and Senetas (1985) reported higher dry matter intakes (2.9% of body weight) for sheep fed groundnut haulms compared with findings of Cheva Isarakul and Cheva Isarakul (1985). The digestibility of groundnut haulms in the latter study was 52%. Alhassan, et al (1984) fed goats with a number of low quality forages namely sorghum stover, maize stover, sorghum leaves and cowpea vines. Dry matter digestibility of these materials were 52, 53, 57 and 47 respectively. Even though the digestibilities observed in this study were comparable to that of Suriyajantratong and Senetas (1985), intakes observed by Alhassan et al (1984) were lower (1.1, 0.7, 2.0 and 0.8% of body weight respectively) than those observed with sheep by the earlier workers. Differences in intake could be associated with animal species differences (Rees and Little, 1980). According to Doyle (1982) and Pearce (1984), materials with such low dry matter digestibilities coupled with low intakes may not satisfy maintenance needs of the animals, hence the need to upgrade the residues to improve their nutritive value.

2.3.2 Factors affecting intake and utilization of straw and other low quality roughages by ruminants

Composition and utilization: It is possible that the components of Dry Matter (DM) rather than DM digestibility may determine intake of low quality roughages. Blaxter and Wilson (1963) suggested 8.5% as the level of Crude Protein (CP) at which the activity of cellulolytic microbes in the rumen might be limited by the availability of Nitrogen (N). Intake of low quality roughages has also been found to be inversely related to the Cell Wall (CW) content of the material (Goering and Van Soest, 1970).

Nutrient Imbalances: There is widespread evidence that imbalance of nutrients such as N and other minerals and vitamins depresses feed intake and animal performance. Liveweight losses resulting from feeding of all low quality roughage diets parallel those on low protein dry season grazing (Rose-Innes, 1960; Larsen and Amaning-Kwarteng, 1976). Anderson (1978) identified CP and Phosphorus (P) as the major deficiencies in straws; Calcium (Ca) levels are marginal and (Zn) deficiency could arise when straw is fed for extended periods. To achieve maximum intake of straw, a CP content of 66-85 g/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 (RDN) is limiting, but also total DM and Organic Matter (OM) intakes. Church and Santos (1981) observed that with small amounts of

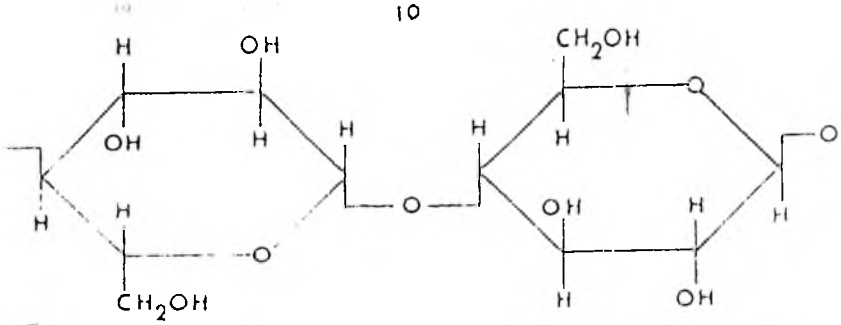

Figure 2.1a The cellulose unit β-1, 4 linked glucopyranose

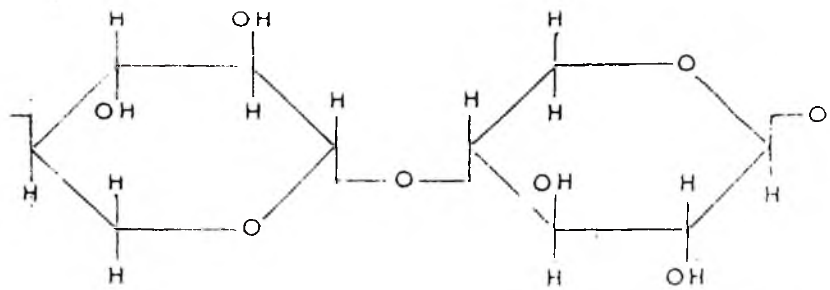

Figure 2.1b The hemicellulose unit β-1, 4 xylopyranose

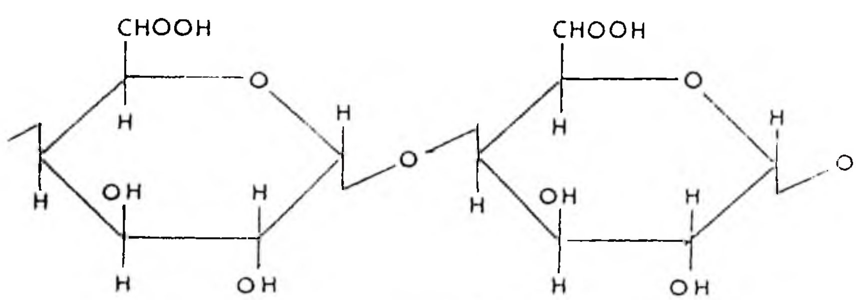

Figure 2.1c The pectin unit 1-4α, galactopyranuronic acid

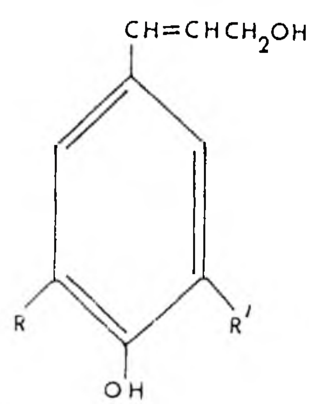

Figure 2.1d The basic lignin unit, derived from phenyl propane. R may be H or $-OCH_3$

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).

2.3.3 Chemical composition of rice straw

The major fraction of roughage (up to about 85% of cereal straws) is structural cell wall (CW) which is ligno-cellulosic in nature and consists mainly of the polysaccharides cellulose, hemi-cellulose, pectin and their derivatives and the non-polysaccharide component, lignin. These exist in close physical and chemical association. They can vary widely in properties depending on the relative proportions of the components and their chemical bonding and distribution in CW. The manner in which the components are complexed with each other and with minerals is also a source of variation (McManus, 1981).

Cellulose: This is usually the most abundant structural polysaccharide molecule. It is largely crystalline and organised as microfibrils held together in matrix of largely amorphous non-cellulose polysacharides, lignin and some glycoprotein. Cellulose (Figure 2.1a) is a linear polymer of high molecular weight built up of up to 10,000 beta-1, 4-linked glucose units. The conformation obtained with this type of linkage strongly favours the formation of hydrogen bonding between sugar units in the chain and between adjacent chains. Cellulose is characterised by high mechanical strength and resistance towards chemicals. The acccessibility of cellulosic materials to enzymatic hydrolysis may vary considerably and can be increased by treatments which increase the surface area, make the cellulose less crystalline, more swollen or less affected by components such as lignin and silica.

Hemicelluloses: These are amorphous polysaccharides made up of relatively short chains of xylose or other pentoses (Figure 2.1b) or of a mixture of glucose and mannose, linked as with cellulose, in beta-1, 4 structures. The hemicelluloses have many side chains but those in straws are almost entirely glucurono-arabino-xylans with side chains of D-glucuronic acid and L-arabinose. Hemicelluloses exist in close association with cellulose and lignin and vary widely in content from one type of plant material to another with a range of about 6 to 40%. Like cellulose, the indigestible hemicellulose fraction is largely encrusted with lignin.

Pectin: This is the third type of polysaccharide in CW and is based on galactose in the form of D-galaturonic acid residues joined in alpha-1, 4 linkages (Figure 2.1c).

Lignin: Accompanying the structural polysaccharides is lignin, an inert and complex polymer that is based on derivatives of phenyl propane (Figure 2.1d). Lignin is encrusted into the CW and establishes covalent bonding to hemicelluloses, forming so-called ligno-carbohydrate complexes. Lignin may also be linked to other CW constituents by covalent bonds. Straw lignins have not been studied in great detail but investigations of ligno-carbohydrate complexes in wood have shown that lignin is bound to different types of sugar units and to uronic acid residues in the hemicellulose.

Lignin has a number of functions essential to the plants, the major one of which is to supply strength and rigidity. Its nutritional significance lies in its indigestible nature. By way of its close physcial and/or chemical assocation with the CW polysaccharides, it frequently acts as a physical barrier and impedes the microbial breakdown of these compounds.

Cutin

Cutin, the external sheet-like material on plant surfaces is similar to lignin in protecting CW carbohydrates from microbial digestion.

Minerals

McManus, et al (1979) estimated the mineral content of CW to range from 2 to 20%. The solubility of this fraction is important in determining the quality of the roughage. Jones and Handrick (1965) reported that almost all the insoluble fraction consists of silica which is present as inclusions within the CW or as encrustations on the CW (Jones and Handrick, 1967) where it might influence the digestibility of CW (Baker and Harris, 1947). Using a regression approach, Van Soest and Jones (1968) showed that each percentage unit of silica reduced in vitro DM and OM digestibility by 3.0 and 1.4 percentage units respectively. By contrast silica was found to have no effect on in vivo OM digestibility of Panicum spp. (Minson, 1971) or legumes (Van Soest & Jones, 1968). These apparent differences could be explained by the position of silica within the plant tissue. Minson (1976) reported that silica could be contained in specialized epidermal cells where it is likely to affect the digestion of other fractions. It is also possible that other indigestible fractions may also protect the CW from digestion. The ash content of rice straw has been reported to be about three times higher than in other straws (Van Soest & Jones, 1968). This is associated with the higher silica content of rice straw than other straws (see Table 2.2 and 2.3). It should be stressed that mineral contents vary widely depending on factors such as agronomic factors, amount of soil contamination and plant variety.

Other physical and chemical CW factors which act as barriers to microbial degradation are suberin, waxes, hairs, moisture content of CW, surface area exposure of cellulose, phenolic acids and acetyl groups.

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	1.5-2.5	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
Sugarcane tops	90	20-22	82-83	15	3-3.5	42-46
Banana leaves	80	5-8	81-95	28-34	1.5-2.5	44-54
Banana Pseudostems	90	10-15	91	24	12	45
Cocoa Pods	75	2-9	86-91	21-32	2-3	61
Oil Palm	56	2-9	75-90	20-45	1-4	33-56
Fruit bunch		3-4	95	-	6-8	-

987).

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

Crop Residue	% DM								
	Cell Wall (NDF)	Cell Content	ADF	Lignin	Cellulose	Hemi-Cellulose	Silica	$T^{1}/2$ (Hr)	% DM losses (24h)
Maize stover	70-80	-	-	7-9	43	24	5	70	30-80
Sorghum stover	75-75	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 Vines	75	-	-	5-6	-	-	-	-	-
Cassava tops	30-45	20	-	-	-	-	-	30-50	45
Sugarcane top	65-75	-	43	5-6	-	-	-	50-128	10
Banana leaves	40-60	10	-	-	-	-	-	50-60	-
Banana Pseudostems	35-40	10	-	9-10	35	18	-	40-50	50

Source: Smith, (1987).

Table 2.2. and 2.3 show some values for the chemical composition of some crop residues. The very high $T^1/2$ values (i.e. time taken for half the material in a sample to be degraded in the rumen) (Table 2.3) of most of the residues confirm their poor degradability in the rumen. Such slow rates of degradability mean low rates of uptake of the material from the rumen and therefore low intake of Total Digestible Nutrients (Smith, 1987).

2.3.4 Microbial Degradation of fibre in the Rumen

Plant fragments entering the rumen or hindgut become extensively colonized by bacteria within an hour (Cheng et al, 1981. Treating plant fragments to detach bacteria shows that at least as many organisms associate with particles as remain free in the rumen liquor (Minato and Suto, 1978). Preference is always shown for damaged areas during primary colonization. Chewing by the animal and methods of feed preparation which maximise damage thus promote colonization and have a marked effect on rates, if not on the ultimate extent of degradation.

The ligno-cellulosic complex accounts for most of the organic matter (OM), and hence, gross energy of common roughages. Nutritionally, Pigden and Bender (1972) divided ligno-cellulose of low quality roughages into three distinct categories: the unavailable fraction including compounds such as lignin which for practical purposes, is not degraded by rumen microflora; the digestible energy (DE) fraction representing carbohydrates which are normally available for microbial degradation and the potentially digestible energy

(PDE) which includes the carbohydrates not normally available to rumen microflora due to chemical and/or physical association with the ligno-cellulose complex, but which can be made available by appropriate treatment or by supplementation. In young forages the PDE fraction is relatively insignificant because most of the carbohydrate material is available to the rumen microflora. As the plant matures and lignification proceeds, more of the carbohydrates is "tied up" and in unprocessed mature forages the PDE fraction may be as large as the DE fraction.

Urea ammoniation like sodium hydroxide treatment makes this PDE fraction available to the animal.

2.4 IMPROVEMENT OF NUTRITIVE VALUE OF CROP RESIDUES

2.4.1 Introduction: In order to increase the nutritional value of straws and other low-quality roughages for the utilization by ruminants a number of processing methods, namely: physical, chemical, and biological (Table 2.4) have been used to rupture the cellulose-lignin complex by extraction or decomposition of lignin and thus make structural carbohydrates more accesible for breakdown by rumen microbes, and supplementation to overcome specific nutrient deficiencies.

Two fundamental considerations to be made on the feasibility of processing roughages 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.

2.4.2 Physical Treatment

Physical treatment has been found to increase intake of crop residues (Chaturvedi, Singh and Ranjhan, 1973; Adu and Lapkini, 1983). Of the physical processes listed in Table 2.4 those appropriate for small scale farming systems in Ghana include chopping and grinding.

Chopping and Grinding

It has been found that such physical treatments of straw increases their daily intake of animals. This is due partly because the density of the feed may, be increased and partly because chewing time required to reduce ingested material to a particle size suitable for digestion by rumen microorganisms is decreased considerably. However grinding produces more or less fine material that may pass through the digestive tract too rapidly for maximum nutrient utilization.

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

Physical	Chemical	Physico/Chemical	Biological
	Alkali Treatment		
1. Soaking and/ or welting	1. Sodium Hydroxide	1. Grinding/ Chemicals	1. Composting
2. Chopping	2. Calcium hydroxide	2. Pelleting/ Chemicals	2. Ensiling
3. Grinding and pelleting	3. Potassium hydroxide	3. Steaming/ Chemicals	3. Fungal growth
4. Boiling	4. Anhydrous ammonia		4. Enzyme addition
5. Ball milling	5. Ammonium hydroxide		
6. Gamma irradiation	Acid treatment		
	1. Sulphuric acid		
7. High pressure steaming	2. Hydrochloric acid		
	Oxidation		
	1. Sulphur dioxide		
	2. Oxone		
	3. Chlorine and chlorinated compounds		

Source: Smith, (1987).

2.4.3 Chemical Treatment

The three classes of chemicals currently being used to treat fibrous residues are alkalis, acids and oxidizing agents. All three are capable of weakening cell wall component complexes (lignin-carbohydrates), solubilizing the components (lignin, cellulose, etc.) and increasing the swelling capacity of the cell wall thus facilitating microbial enzyme entry (Smith, 1987).

2.4.4 Use of Sodium Hydroxide

Sodium hydroxide is generally regarded as the most effective alkali for improving the digestibility of crop residues. Increasing *in vitro* digestibility (up to 38% units) as well as *in vivo* digestibility (24-30% units) and intake of treated crop residues (about 30%) have been reported by Amaning-Kwarteng, 1991).

The responses 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 all 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 passage from the rumen at high levels of NaOH application.

In spite of the effectiveness of NaOH in improving crop residues feeding value, it can hardly be recommended for use on small scale farms because of problems of availability, cost and handling.

2.4.5 Use of caustic ash of some crop residues

A number of workers reported high levels of potash in the ash of a number of crop residues, (Adebowale, (1985), Smith (1987), Smith and Osafo (1987).

Adebowale (1985) found that potassium concentration in cocoa pod ash, for example was about 44mg/kg. The amount of hydroxyl ions (OH) present in the ash solution as NaOH and KOH was 20.5 and 28.7 percent respectively. He also reported that titrimetric and potentiometric analyses showed that about 4.4 kg of cocoa pod ash was equivalent to 1 kg of NaOH.

Even though the use of crop residue ash solution from some crop residues, e.g. cocoa husk, may sound a better alternative to NaOH treatment, these sources of alkali are used extensively by local farmers for the production of soap, an industry which is regarded as an alternative source of income for the farmers.

2.4.6 Use of Ammonia

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

The use of NH_3 as an anhydrous gas or as aqueous NH_4OH has improved digestibility and voluntary intake similar to that achieved with NaOH when conditions for treatment were appropriate (Sundstol *et al*, 1978). The use of NH_3 also avoids the problems arising from the use of NaOH (e.g. accummulation of residual alkali).

2.5 UREA TREATMENT

When urea is decomposed, it releases NH_3 according to the formula:

$$(NH_2)_2CO + H_2O \longrightarrow 2NH_3 + CO_2$$

Molecular weight	60	18	34	44

Addition of 6.3% (wt/wt) of urea to straw is equivalent to adding 3.5% NH_3, assuming 100% conversion (Sundstol and Coxworth, 1984).

The NH_3 liberated from urea, in the presence of water, produces the alkali NH_4OH which acts on the lignocellulose complex of the straw and loosens the bond between the lignin and cellulose.

2.5.1 Factors influencing the effect of urea treatment

According to Cloete and Kritzinger (1984) and Guessous et al (1989), success with urea treatment depends on:

a) Urea level

b) Length of treatment

c) Moisture content of straw

d) Environmental temperature

e) Urease activity

f) Type and quality of material being treated.

Economides (1986) treated straw with a 10% urea solution at the rate of 400l/t straw and stored in sealed containers for 1, 15, 30, 45 and 60 days. He observed that *in vitro* organic matter digestibility did not change significantly after 30 days of incubation. Similar observations were made by Jayasuriya and Perera (1982) who treated straw with 4% urea solution. Optimal results were achieved after 3-4 weeks. Jayasuriya (1985) on the other hand reported no signficant change beyond 10 days of incubation. Alhassan and Aliyu (1991) also reported no significant change beyond 7 days of incubation of maize straw with 4% urea solution.

The effect of moisture level on the ammoniation of low quality roughages was investigated by Sundstol, Coxworth and Mowat (1978), Solaiman, Horn and Owens (1979) and Cloete and Kritzinger (1984). Sundstol et al (1979) found that increasing the moisture content from 12 to 50% had a positive effect on the in vitro organic matter digestibility of ammoniated straw. Cloete and Kritzinger (1984) also observed a higher in vitro organic matter digestibility at 37.5% moisture level than at 25% moisture level. Excessive moisture content of treated straw may however increase mould formation and enhance handling problems.

In general, chemical reactions run faster at high rather than at low temperatures. Cloete and Kritzinger (1984) observed an increase in effectiveness of ammoniation when temperature was increased from $4^{o}C$ to $35^{o}C$. Sundstol et al (1979) also found a positive effect of increasing temperatures from -20^{o} to $+ 25^{o}C$, but the effect was more prominent at 8 weeks than at 4 weeks of treatment. This indicated that, at least, part of the temperature effect can be compensated for by increasing the time of treatment.

Efficiency of ammoniation has also been reported to be influenced by the availability of urease in the medium.

The optimum temperature for urease activity in soil as indicated by Du Preez (1983) is approximately 30°C. According to Orskov, et al (1983) urease activity tends to decrease at temperatures lower than 20°C. Sundstol and Coxworth (1984) cautioned that unless maximum urea decomposition was ensured, very high levels of urea could remain in the straw, and be potentially dangerous to livestock. Guesssous et al (1989) working on Moroccan straws reported that the straws naturally contained urease enough to hydrolyse added urea even during the coldest months of winter. Urea treatment was, however, found to be more effective at ambient teperature of about 12°C daily mean.

The importance of an airtight container (or silo) for storing the straw during urea ammoniation has been a matter of debate (Sundstol and Coxworth, 1984). Ibrahim Fernando and Fernando (1983) compared various types of silos for urea ammoniation of straws. The results, which have been presented in their decreasing order of effectiveness are shown in Table 2.5. As the silos became less airtight, the degree of mouldiness increased, DM intake decreased and apparent DM digestibility also decreased. Saadullah, Hague and Dolberg (1981) as cited by Sundstol and Coxworth (1984) observed that bamboo baskets seemed as good silos for urea treatment of straw as did the earthern pit.

Table 2.5: The effect of silo type of mould attack, digestibility and intake of urea ensiled rice straw (Ibrahim, Wyeratne and Costa, 1983)

	Moulded %	DM Digestibility (%)	DM intake g/kg.d
1. Earthern pit	3	61	55
2. Polythene bag	18	60	51
3. Coconut leaves	31	60	47
4. Urea bags	37	57	46
5. Big bag	41	58	38
6. Open stack	36	53	40

2.5.2 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 tef (*Eragrostis tef*) straw, oat straw and mixed legume haulms are approximately doubled 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.

Ali (1986) dissolved 5kg urea and 10kg cattle manure in 40 litres of water. The mixture was poured over 100kg of straw which was covered with mud for between 4 and 6 weeks. He observed that intake of sheep fed this treated diet rose from 400 to 800g/day. Liveweight gain of the sheep was 5% more than animals on untreated straw.

Studies by other workers (Dolberg, et al 1982; and Wanapat et al 1982) have indicated that ensiling straw with urea (3-5%) increased the digestibility by 10-12% units The straw had a moisture content of 50% and was incubated for 2-3 weeks.

Saadullah et al (1981), as cited by Sundstol and Coxworth (1984), measured the intake and digestibility of rice straw treated with urea, (Table 2.6). Results obtained indicated that urea ammoniation increased the feeding value of

Table 2.6: Protein content, intake, (OMI) and digestibility (OMD) of urea-treated rice straw (Saadullah et al, 1981)

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

straw to the same extent as that normally found in experiments with anhydrous or aqueous NH_3. Guessous et al (1989) found that treatment with 6% urea at 30% moisture level increased crude protein content of straw from 6 to 8% and IVOMD from 51-59%. Intake of straw also increased significantly.

2.5.3 Supplementation

According to Deverdra (1985), 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 2.7 show that crop residues rarely meet these requirements.

Chemical or other treatments reviewed earlier may improve intake and digestibility but unless adequate supplementation of deficient nutrients is made, much of the additional energy released will be inefficiently used (Smith, 1987). Adequate supplementation is therefore required for efficient utilization of crop residues.

Preston and Leng (1987) have suggested that to optimise the utilization of crop residues, nutritional supplements should provide the following in order of preference:

1. High concentration of fermentable carbohydrates (CHO).
2. Fermentable nitrogen (3gH/100g fermentatble CHO).
3. Adequate rumen ecosystem:
   (i) Roughage characteristics
   (ii) Micro-nutrients
   (iii) Control of protozoal activity

4. By-pass nutrients

   (i) Protein

   (ii) Energy

5. Balance of end-products of digestion. Supply of:

   (i) Amino acids

   (ii) Glucose and glucogenic compounds in relation to total oxidative energy and tissue needs.

Table 2.7: Voluntary intake and digestibility of selected crop residues

Crop Residue	% CP	Intake % BW		Dry Matter digestibility	
		Sheep	Goat	Sheep	Goat
Maize stover	4.0	-	0.7	-	53
Sorghum stover	4.0	-	2.0	-	57
Rice straw	4.2	1.4	1.9	47	48
Cocoa pod	5.0	-	-	20	-

Source: Smith, 1987.

The first four ensure an adequate rumen ecosystem, while the last 2 complement the needs of the animal as a whole.

Table 2.8 shows a list of some of the potentially valuable supplements.

Table 2.8: Possible sources of nutritional supplements to crop residues in Ghana

Nutritional Factor	Supplement
Fermentable Nitrogen	Urea, urine, animal manure, ammonium sulphate.
Fermentable Carbohydrate	Molasses cane juice, cassava chips, cassava peels, reject banana/plantain, rice bran, maize bran, starch.
Roughage-micomutrients	Forages, such as Gliricidia, leucaena, water hyacinth, cassava tops, sugar cane tops, sorphum tops, banana leaves and pseudostems.
By-pass protein	Oil seed cakes, leucaena, Gliricidia, other tannin rich forages, fish meal
By-pass energy	Starch, corn, broken rice, rice polishings

CHAPTER 3

EXPERIMENT 1

3. TITLE: Determination of optimum urea concentration, moisture level and treatment time for urea ammoniation of rice straw in Ghana.

3.1 INTRODUCTION

Ammoniation of straw by ensiling with urea, even though inexpensive and uncomplicated, requires a treatment period of approximately six to eight weeks (Kritzinger and Franck, 1981).

The effect of moisture level on the ammoniation of straw was investigated by various workers with moisture levels ranging from 8% to 54%. It can be concluded in general that ammoniation was consistently faster at higher moisture levels.

In this study, the effect of urea concentration and moisture level with various treatment periods and their interactions were investigated simultaneously.

3.2 MATERIALS AND METHODS

3.2.1 Location of experiment: This experiment was carried out in the Nutrition Laboratory of the Department of Animal Science, University of Ghana, Legon.

Treatments: Rice straw (local variety), obtained from Kpong farms, was chopped into about 3cm length. Hundred grammes of the rice straw were weighed into each of 72 polyethylene bags and subjected to various treatments as indicated in Table 3.1.

Table 3.1: Various treatment conditions affecting-ammoniation of rice straw and the levels studied in experiment 1

Factor	Level	Amount added per 100g DM rice straw
1. Urea concentration (%)	3.5	4.05g
	5.0	5.78g
	6.5	7.52g
	8.0	9.25g
2. Moisture level (%)	40	44.10cm3
	50	72.92cm3
	60	116.17cm3
3. Treatment period (days)	7	-
	14	-
	21	-

3.2.2 Experimental Design: The treatments constituted a 4 x 3 x 3 factorial experimental design, the factors being urea concentration, moisture level and treatment period.

3.2.3 Ammoniation process: The various amounts of urea were dissolved in the respective amounts of distilled water and sprinkled on the straw in the polythene bags. After the contents of each bag had been thoroughly mixed, the bag was made airtight by sealing with masking tape. The bags were kept in a room with an average ambient daily temperature of 28°C. Bags were opened after 7, 14 and 21 days of ensiling. Each sample was then divided into 2 and aired for 30 minutes and 24 hours respectively.

3.2.4 Chemical Analysis: Residual Nitrogen (N) content of the samples was determined by the Kjeldahl analysis (AOAC, 1975). Samples were also analysed for Organic Matter (OM), Acid detergent fibre (ADF) and Neutral detergent fibre (NDF).

3.2.5 <u>In Vitro Digestibility</u>: Three sheep (wethers) with an average weight of 24kg, obtained from the Agricultural Research Station, Kade, were drenched with Rametin (N-diethoxy phosphoryloxy - naphthalimide, Bayer Levekusen, Germany) and N.C.A. (Cooper, The Wellcome Foundation Ltd., London, Great Britain) and dipped with Gamatox (gamma B.H.C. 20% w/v, Cooper McDougall and Robertson Ltd., Berkhamsted Herts, England) to render them free of endo-and ectoparasites. They were ruminally fistulated (Preston, 1986) and kept in conventional metabolism crates at the Agricultural Research Station, Legon. A recovery period of about 3 weeks was allowed during which intramuscular injection of 'Pennicillin' antibiotic (5ml) was administered daily for 5d. The animals were fed a diet of <u>Panicum maximum</u> and urea-treated straw in the ratio of 1:2. This was to ensure that the desired microbes were available for the <u>in vitro</u> digestibility trial. Water was given <u>ad libitum</u>.

Rumen liquor was then collected from each sheep by means of a suction pump and a stomach tube passed through the fistula. Coarse particles of food were removed by straining the liquor over a muslin sheet into a suction bottle. About 85ml rumen sample were removed from each animal and transported to the laboratory in a thermos flask for in vitro analysis (Tilly and Terry 1963).

3.3 RESULTS

Composition of untreated straw: The mean chemical composition of untreated rice straw is shown in Table 3.2.

Table 3.2: Chemical composition and In vitro or organic matter digestibility (IVOMD) of untreated rice straw

DM	88.10
N	1.03
NDF	86.32
ADF	48.91
Hemicellulose	37.41
Cellulose	30.04
Lignin	10.99
Org. Matter	76.89
IVOMD	40.09

Cellulose and hemicellulose together formed about 67% of the DM, 47% of OM and about 78% of the cell wall component. Nitrogen content was 1.03% of DM (i.e. about 6% CP).

Residual N content: Nitrogen content of straw aired for 30 minutes and 24 hrs as influenced by level of urea, length of treatment period and moisture level is shown in Tables 3.3 and 3.4 respectively. Interactive effects on quality of ammoniated straw after airing for 24 hours are shown in Fig. 3.1 to 3.6.

Table 3.3: Percent Nitrogen content of straw aired for 30 minutes as influenced by level of urea, length of treatment and moisture level

Treatment period (days)	Mean N Content (%)	Urea level (%)	Mean N Content (%)	Moisture level (%)	Mean N Content (%)
7	3.11^{a}	3.5	2.15^{a}	40	3.10^{a}
14	3.02^{a}	5.0	2.73^{b}	50	2.96^{b}
21	3.12^{a}	6.5	6.41^{c}	60	3.20^{a}
		8.0	4.05^{d}		
S.E.	0.07	S.E.	0.08	S.E.	0.07

Means in the same column with different superscripts differ significantly (P 0.05).

Table 3.4: Percent Nitrogen content of straw aired for 24h as influenced by level of urea, treatment period and moisture content

Treatment period (days)	Mean N Content (%)	Urea level (%)	Mean N Content (%)	Moisture level (%)	Mean N Content (%)
7	1.30^{a}	3.5	1.31^{a}	40	1.63^{a}
14	1.35^{a}	5.0	1.24^{a}	50	1.24^{b}
21	1.42^{a}	6.5	1.38^{ab}	60	1.27^{b}
		8.0	1.60^{b}		
S.E.	0.10	S.E.	0.11	S.E.	0.10

Means in the same column with different superscripts differ significantly (P 0.05).

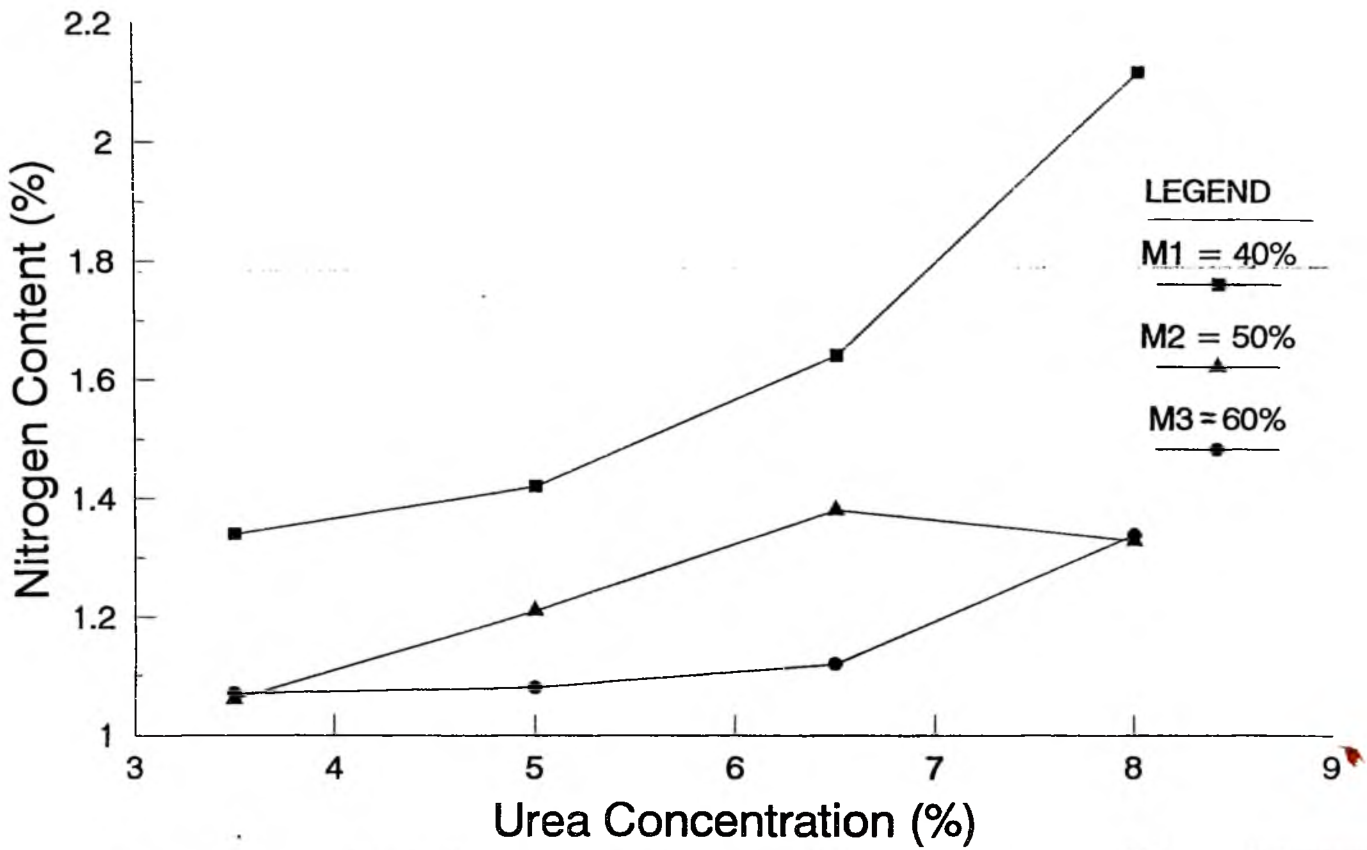

Figure 3.1. Interactive effect of Urea Concentration and Moisture level on Nitrogen content of Urea - Ammoniated rice straw

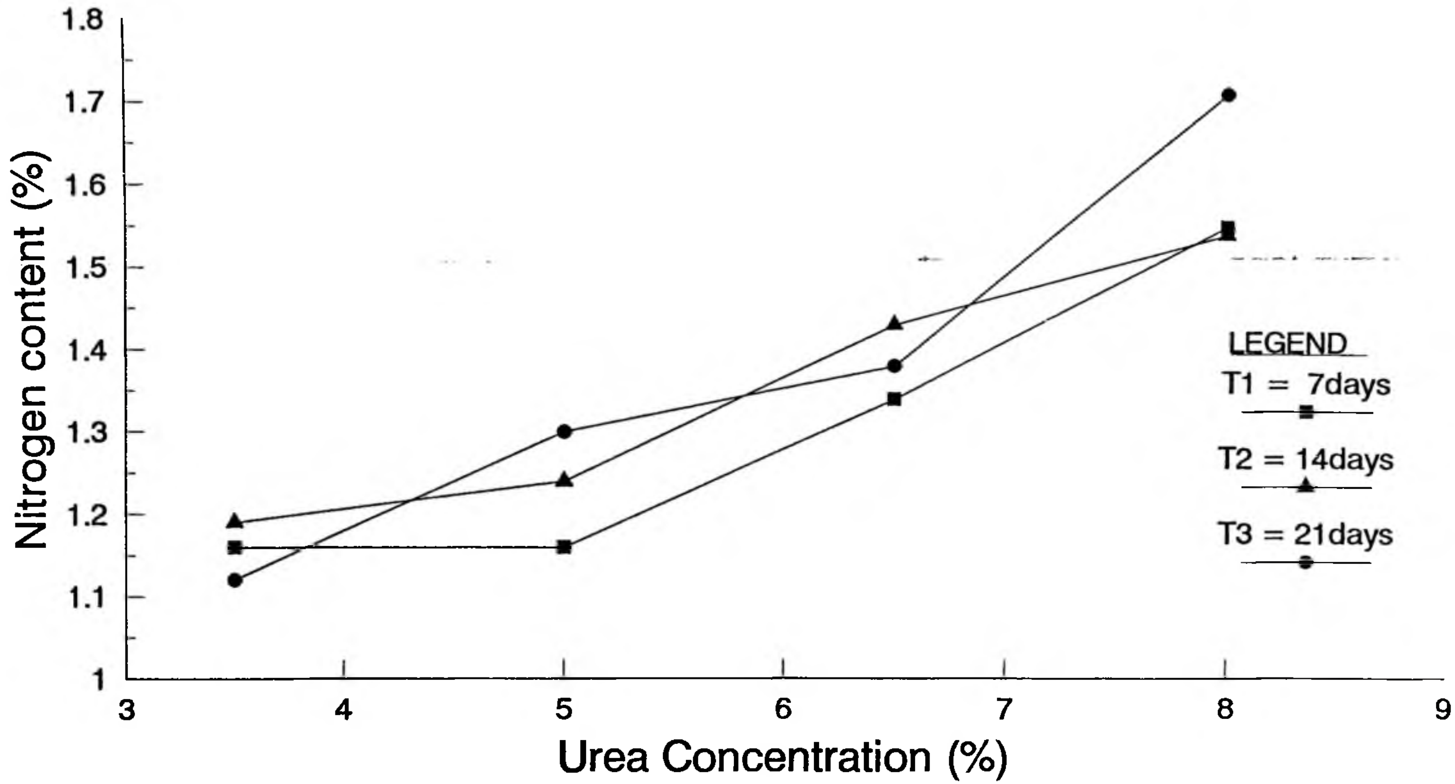

Figure 3.2. Interactive effect of Urea Concentration and treatment period on nitrogen content of Urea - Ammoniated rice straw

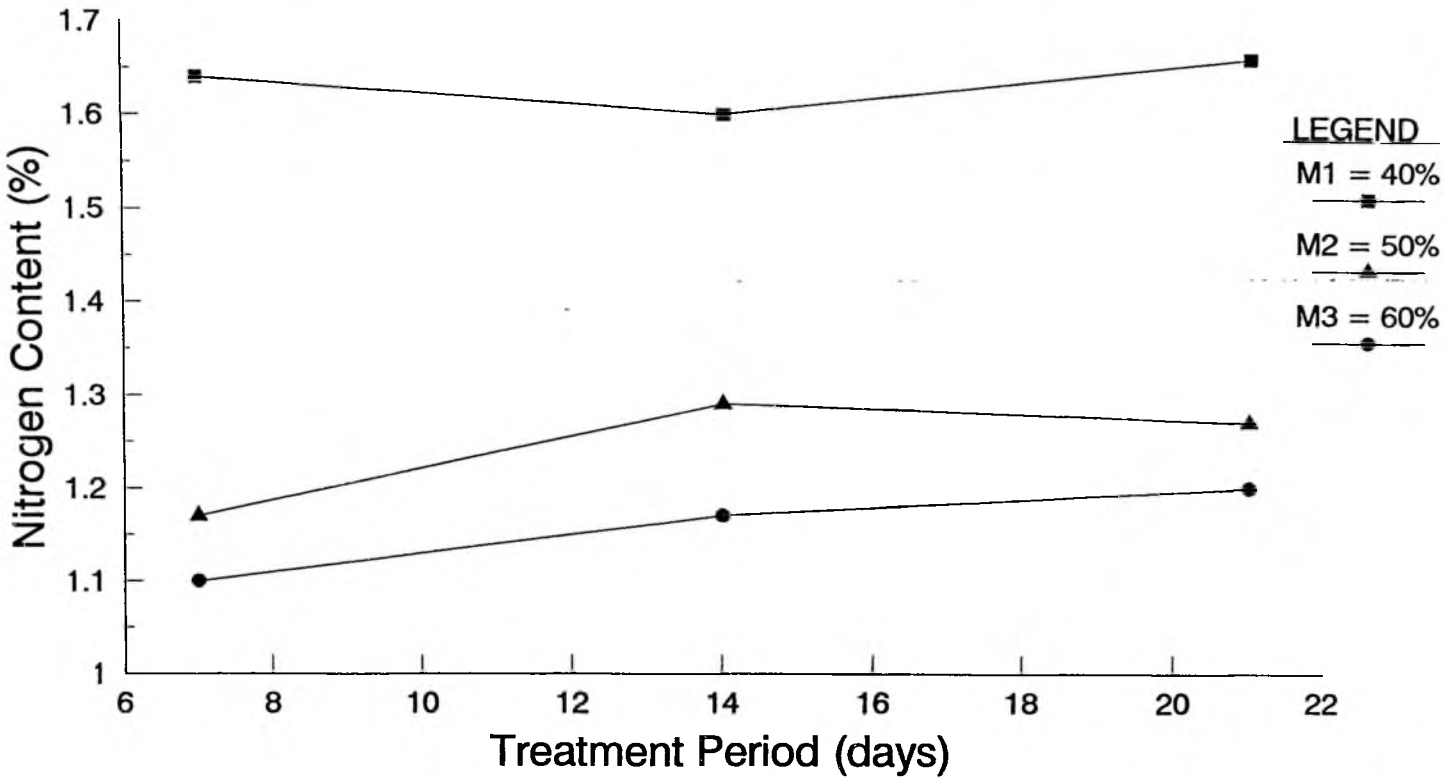

Figure 3.3. Interactive effect of moisture level and treatment period on Nitrogen content of Urea - Ammoniated rice straw

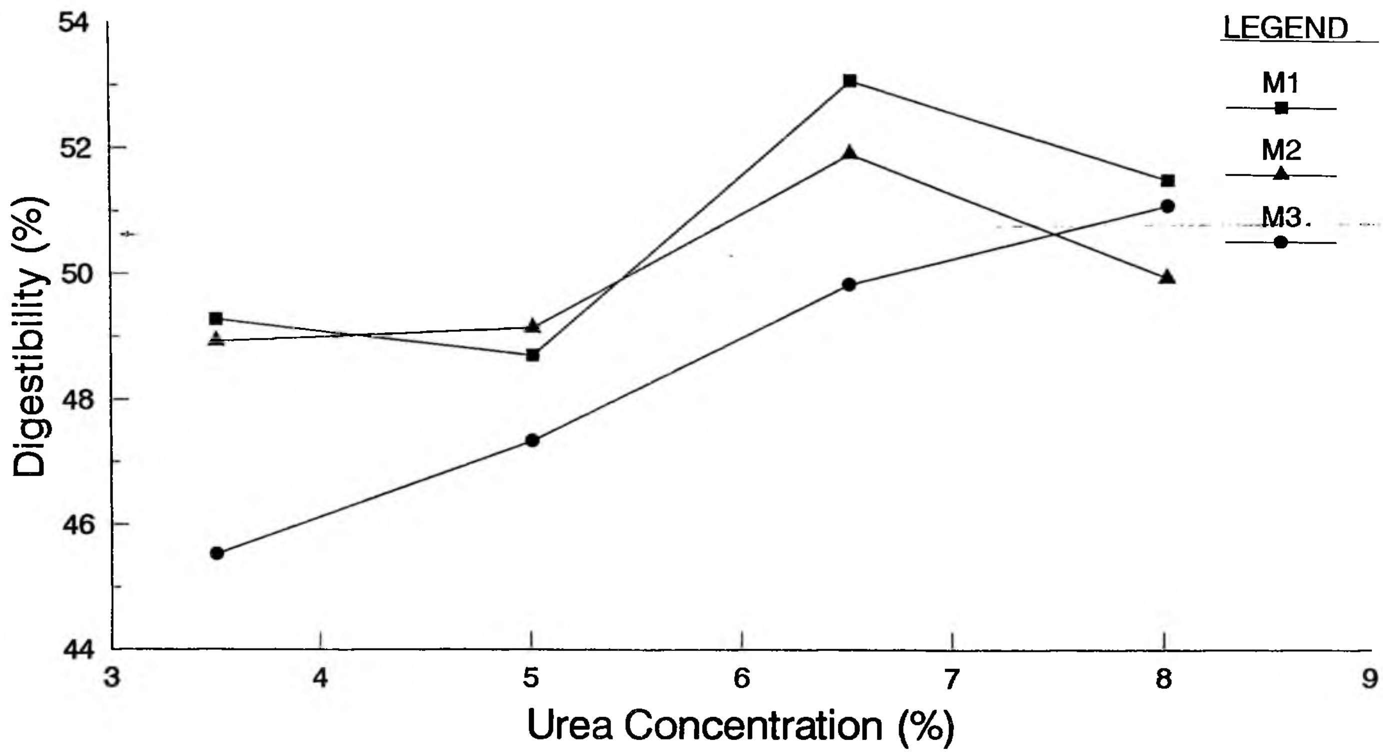

Figure 3.4. Interactive effect of Urea Concentration and Moisture level on the in vitro organic matter digestibility of Urea - Ammoniated rice straw

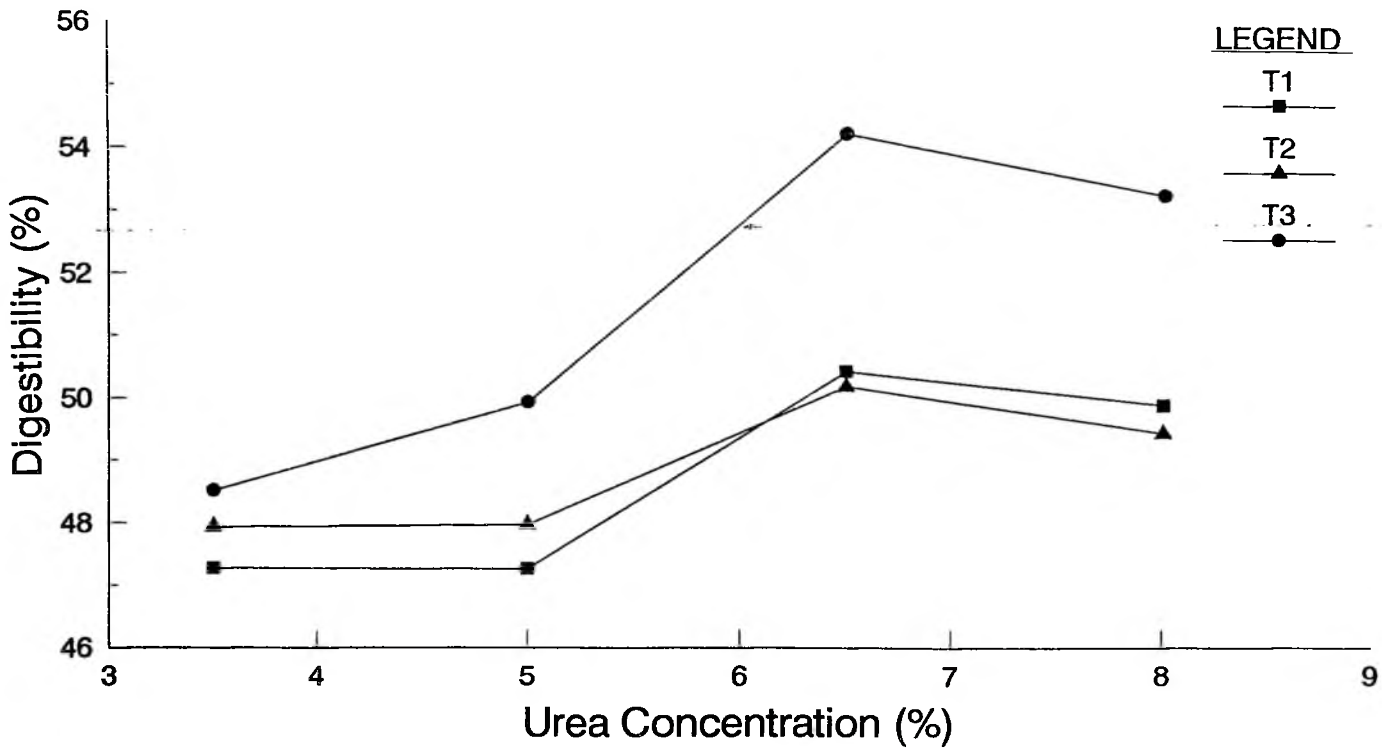

Figure 3.5. Interactive effect of Urea Concentration and treatment period on the in vitro organic matter digestibility of Urea - Ammoniated rice straw

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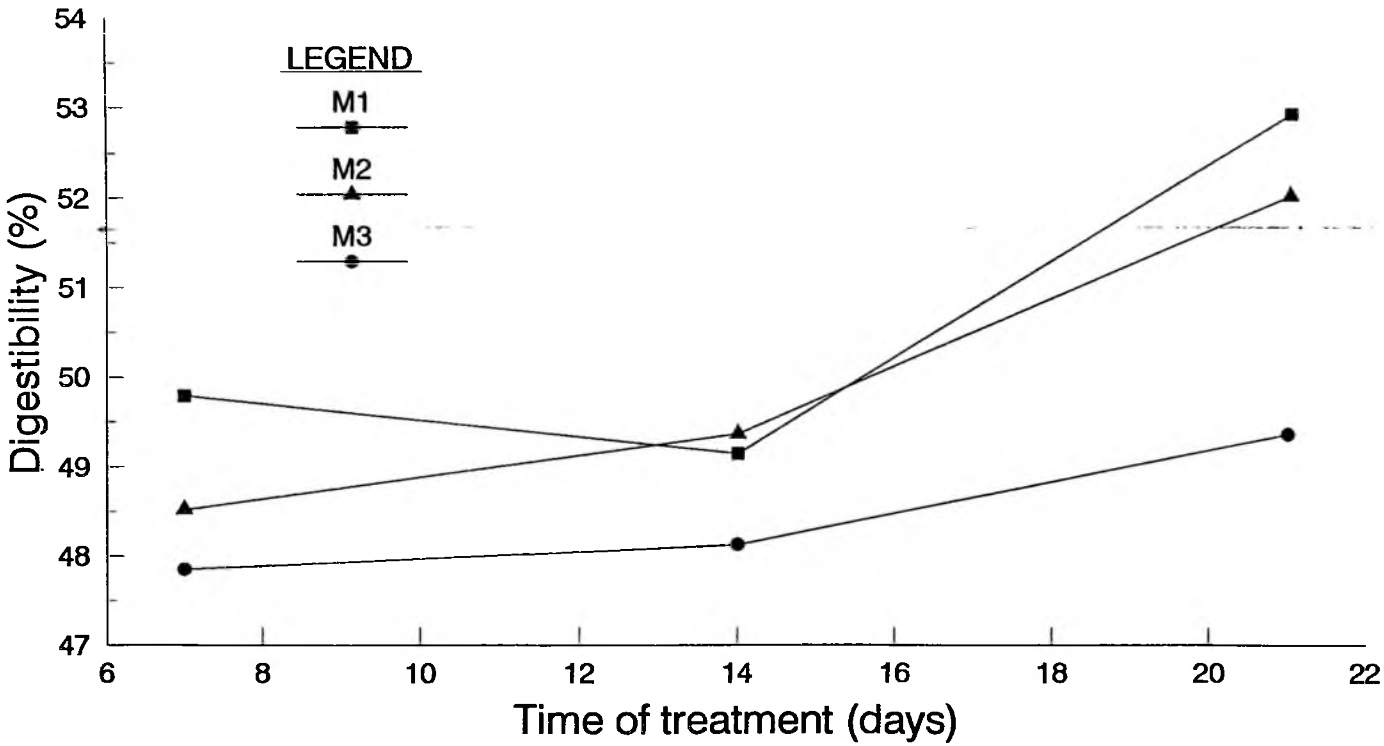

Figure 3.6. Interactive effect of moisture level and treatment period on the in vitro organic matter digestibility of Urea - Ammoniated rice straw

The highest residual nitrogen at all urea concentrations was found when urea was applied at 40% moisture level; while 60% moisture level recorded the lowest residual nitrogen content, (Fig. 3.1). While 8% urea concentration and 40% moisture gave the highest residual nitrogen, 6.5% urea and 40% moisture gave the highest IVOMD, (Fig. 3.4). IVOMD decreased after 6.5% urea for 40% and 50% moisture while it continued to increased after 6.5% urea for 60% moisture.

In Fig. 3.2, residual nitrogen increased with increasing urea concentration and was highest when straw was stored for 21 days. IVOMD was also higher for 21 days than 7 and 14 days (Fig. 3.5). The peak for all three periods was at 6.5% urea after which there was a decrease in IVOMD.

Figure 3.3 depicts a higher amount of residual nitrogen at 40% moisture level compared to 50% and 60% moisture levels with respect to treatment time. The highest IVOMD however was recorded at 21 days with 40% moisture.

3.4 DISCUSSION

Chemical composition of untreated straw

The chemical composition of rice straw determined in this experiment agrees with values quoted by Smith (1987). However, the crude protein (CP) content determined in this experiment was higher than that reported by Otchere et al (1977) (2.90%)). Differences such as these in chemical composition could be attributed to differences in cultural practices during the cultivation of the crop, stage of harvesting of the crop, climatic conditions prevailing, variety of crop and handling and storage of the residue (McDonald Edward and Greenhalgh, 1986).

Residual N: In ammoniating straw with urea solution gaseous ammonia is released which produces NH_4OH in the presence of water. This NH_4OH reacts with the straw to improve its feeding value. The reaction appears to be similar to that of anhydrous or aqueous ammonia both of which have been proved effective in improving the nutritive value of low quality roughages (Sundstol et al, 1978).

Straw incubated with urea and aired for 30 mins contained more residual N than straw aired for 24h. Thus more of the excess NH_3 escaped when straw was aired for 24h. Even though N-content of straw depends on the level of urea used to treat it, Verma and Jackson (1984) reported that a third to half of the nitrogen applied as urea is lost when treated straw is aerated before feeding. Straw Utilization Project (SUP, 1986) reported that intake of straw increased when urea ammoniated straw was aerated for about 24h.

Residual N and IVOMD: The residual N analysed after 24 hrs aeration may give an indication of the level of unhydrolysed urea remaining on the straw after incubation; as the moisture level reduces and urea concentration increases, the amount of unhydrolysed urea increases (Fig. 3.1). 8% urea concentration therefore gave the highest residual N at 40% moisture. IVOMD decreased after 6.5% urea (Fig. 3.4) at 40% and 50% moisture probably because there was not enough ammonia to break up the lignocellulosic bonds to render the straw more degradable. This was probably due to the presence of more unhydrolysed urea in the straw at 40 and 50% levels. Thus 6.5% urea and 40% moisture gave the most effective condition for hydrolysation and production of ammonia.

The highest amount of residual N which was recorded with shorter periods of incubation (Fig. 3.2 and 3.3) compared to the longer period of incubation could be explained by the fact that the longer the incubation period the higher the chance for microbes to hydrolyse the urea and thereby lower the residual N content. This is associated with higher NH_3 which is reflected in the higher IVOMD shown in Fig. 3.6 at 21 days.

IVOMD: Ammoniation in general increased the organic matter (OM) digestibility of straw by 10-15 units (Arnason and Mo, 1977). The untreated straw used in this experiment had an OM digestibility of 40.09% (Table 3.2) and ensiling with 6.5% urea for 21 days increased the digestibility of straw OM by almost 15% units (Fig. 3.5).

Ammonia is a slow reacting agent but the effect of ammoniation could be accelerated by increasing temperature (Cloete and Kritzinger, 1984). However, under ambient temperatures of between 15 and 30°C, length of treatment would be 1-4 weeks (Sundstol et al, 1978). In the present experiment, 21 days was found to be satisfactory when ambient temperature during the experiment was 28°C.

Sundstol et al (1979) reported that increasing the moisture content of straw up to 50% increased the IVOMD of ammoniated straw, while Cloete and Kriztinger (1984) also reported an increase in digestibility of straw when moisture content was increased up to 37.5%. The optimum moisture level (40%) observed in this study is close to that obtained by Cloete and Kritzinger (1984).

3.5 CONCLUSION

The optimum conditions for ensiling rice straw with urea determined in this experiment are 40% moisture level, 6.5% urea and 21 days treatment period.

treated straw for 24h is recommended.

CHAPTER 4

EXPERIMENT 2

4.0 TITLE: Effect of type of silo on the nutritive value of urea ammoniated rice straw.

4.1 INTRODUCTION

Various types of silos are available to farmers. These include the earthern pit, bamboo silos, baskets, cement containers and sheds. In Ghana the practice of ammoniating straw in silos is not popular with farmers. The types of silo to recommend will depend on results abtained in evaluation studies.

The effect of type of silo on the nutritive value of ensiled straw was investiged by Ibrahim et al (1983). They found bamboo baskets to be similar to the earthern pit with respect to effect on nutritive value of straw.

The objective of this experiment was to determine the effect of type of silo on the nutritive value of ammoniated straw.

4.2 MATERIALS AND METHODS

This experiment was carried out at the University of Ghana's Agricultural Research Station, Legon.

4.2.1 Materials and Experimental Design: Three earthen pits, (150 x 90 x 75cm), 3 baskets (1/2 x 50 x 100cm) and 3 cement culverts (1/2 x 50 x 100cm) were randomly placed in an open space and used to determine the effect of type of silo on the nutritive value of urea-ammoniated rice straw. The silos were lined with polythene sheets and filled with about 50kg chopped

(3cm long) rice straw. The straw was put in layers of about 16kg. Each layer was sprinkled with urea solution at the rate of 75g urea/441cm^3 water/kg straw. These rates were the optimum rates observed in Experiment 1. The straw was then pressed down and covered with polythene sheets kept in place by stones to ensure airtightness.

After a treatment period of 21 days, the silos were opened and straw samples taken from the top, middle and bottom layer and bulked for each silo. Samples were then subjected to the following chemical analyses OM, NDF, ADF and IVOMD (AOAC, 1975).

Statistical Analyses: Data were analysed using a completely randomised design. Differences were determined using Least square differences (LSD) procedures (Snedecor and Cochran, 1981).

4.3 RESULTS

Table 4.1 shows the chemical composition and IVOMD of straw samples taken from the various silos.

Table 4.1: Chemical composition and IVOMD of straw samples taken from the various silos

Type of silo	N	% NDF	% ADF	Hemicellulose	IVOMD
Basket	1.86	79.96	46.66	33.27	50.03
Pit	1.94	76.17	37.60	38.57	52.65
Culvert	1.77	79.08	43.83	35.25	50.55
S.E.	0.99	3.77	12.04	11.72	2.91

Differences among silo types were N.S. (P>0.05)

There were no significant differences within silos for the various parameters tested. However, the earthern pit recorded then highest IVOMD and highest %N, Nitrogen content was higher than the normal recorded for rice straw of 1.03% in all silos tested.

4.4 DISCUSSION

Results obtained in this experiment are comparable to those obtained by Saadullah et al (1981) in Bangladesh, who found earthern pit and bamboo basket silos to have similar efficiencies in terms of OMD and CP content.

All three silos used in this experiment, the basket, the cement culvert and the earthern pit, do not differ significantly in terms at OMD and % N.

Even though there were no significant differences in the earthern pit had a higher N-content and IVOMD than the other silos. Thus in making a choice of which silo to use, the earthern pit which is the cheapest and most practical could be the obvious choice even through much also depends on how much the farmer can afford.

CHAPTER 5

EXPERIMENT 3

5.0 TITLE: Effect of urea ammoniation on rumen the degradation of rice straw incubated in nylon bags.

5.1 INTRODUCTION

The nylon bag technique is useful in giving information as to the possible extent of digestion or degradation in the rumen and the events that led up to it i.e. the rate at which degradation occurs. This measurement of rate is particularly important because it provides information on factors that affect intake of roughages (Orskov and McDonald 1979).

The objective of this experiment is to study the rate and potential extent of digestion of urea ammoniated rice straw and thus obtain information relating to voluntary intake of the straw.

5.2 MATERIALS AND METHODS

Location: This experiment was also carried out at the University of Ghana's Agricultural Research Station, Legon.

Animals: Three rumen-cannulated sheep were used. They were fed the basal diet of urea ensiled rice straw.

Sample: Two grammes each of air-dried urea-ammoniated rice straw (Straw ensiled in an earthern pit at the rate of 75g urea/441cm^3 water/kg straw for 21 days was used), and untreated rice straw, ground to pass through a 2.0mm screen, were weighed into nylon bags which had been oven dried and weighed. DM, N and NDF analyses were performed on samples of the material prior to incubation and on residues following incubation.

Nylon bags: used were 8 x 12xm with pore size of 25μ.

Incubation: Bags containing samples were soaked for 3 min in water to displace air before inserting into the rumen. Two bags were incubated per animal per sample per incubation time. Four bags were tied to a drop line consisting of nylon cord (200mm x 2mm) and weighted with a 20g steel bolt at one end. Two drop lines were incubated at a time in the rumen, attaching the wire hook at the end of the drop line to the fistula cap.

Removal of bags: Sets of bags were withdrawn after 0, 3, 6, 12, 24, 36, 48 and 72h. Unopened bags were dipped into ethanol after removal from the rumen to arrest fermentation. Bags were individually washed gently for 3 mins under running tap water. These bags, still unopened were then dried at 50°C to a constant weight. The dried residue was analysed for DM and NDF. To determine initial washout of DM, duplicate samples of each roughage were placed in the rumen of each sheep concurrently with other samples and then immediately removed. This value was subtracted from the amount remaining in bags at the respective hourly intervals to calculate the percentage of original DM remaining in bags for determination of extent of degradation. Rate of DMD (Dm Disappearance) was determined by regressing the natural logarithm of the percentage original DM remaining vs time according to procedures outlined by Miller, (1980).

Statistical Analysis: Data were subjected to analysis of variance for a randomised complete block design with the straws as treatments and sheep as blocks. Treatment means were compared by the method of Least Significant Difference protected by a significant F-value (Snedecor and Cochran, 1981).

5.3 RESULTS

Rate of DMD from 3 to 72h and extent of DMD at 0, 12 and 72h for urea ammoniated straw (TS) and untreated (US) rice straw are reported in Table 5.1.

Table 5.1: Rate and extent of Dry matter disappearance (DMD) of untreated (US) and urea-ammoniated (TS) rice straw

Roughage	Rate of DMD (3 to 72h) %/h	Extent of DMD (%)		
		0 hr	12 hr	72 hr
US	0.48	11.32	16.46	44.64
TS	0.74	8.14	17.51	58.97

Urea ammoniated straw (TS) had a higher rate of DMD (0.74%/hr) than untreated straw (0.48%/hr), a 21% increase between US and TS. Except at 0 hr, extent of DMD was higher in TS than in US at the times tested (i.e. 12h and 72h).

Nitrogen content (N) and neutral detergent fibre (NDF) values for US and TS after incubation for 0, 12, and 72h are shown in Table 5.2.

Table 5.2: Nitrogen and NDF contents of untreated (US) and urea-ammoniated (TS) rice straw after incubation in the rumen of sheep

		Period of Incubation (h)		
		0	12	72
US	N NDF	0.93 62.47	1.24 59.08	2.60 39.35
TS	N NDF	1.11 59.00	1.16 57.86	3.14 27.85

NDF was generally higher for US than for TS for all hours tested. Amount of NDF after incubation decreased from 0 to 72h by about 23% in US and about 36% in TS.

Nitrogen content of straw was generally lower for US than TS Nitrogen content increased with increase in time of incubation till 72h for both treated and untreated straw being 3.14% and 2.60% respectively.

5.4 DISCUSSION

The nylon bag technique identified differences in rate and extent of DMD between ammoniated and untreated straw. The results which agree with observations of Alhassan and Aliyu (1991) showed that chemical treatment (or urea ammoniation) increases both the rate and extent of fermentation of straw in the rumen. The effect of ammoniation has been to cleave linkages between lignin and hemicelluloses to make the latter and also cellulose (which is embedded in the lignin-hemicellulose complex) more accessible for hydrolyzing enzymes. As a result, in this experiment, urea-ammoniated straw (TS) was degraded at 72h about 14% more than untreated straw (US). The effect of microbial enzymes on degradation begins to show at 12hr, but effect at 0 hr cannot be explained.

Orskov and Kowalczyk (unpublished) as quoted by Orskov and McDonald (1979) also investigated the interaction of chemical treatments using the nylon bag technique. All treatments investigated (SO_2, NH_3, SO_2 + NH_3) had higher rates and extents of DMD than the control (untreated straw). The SO_2 being a source of sulphur had a lower DMD at 72h (62%) than NH_3 (71%). The combination of both gave a higher DMD (80%) than either treatments.

The importance of rate of degradation to the host animal is due to the fact that it determines the speed at which the digestible components are removed from feedstuffs and thus the time which the feed occupies space in the gut. From the results of this experiment, TS would therefore be expected to be digested faster and therefore have a higher turnover rate than US. This is indicated in Table 5.2 where cell wall contents decreased faster in TS than in US.

The increase in N for both TS and US is probably due to the increased adherence of rumen microbes to the cell walls of the straw to effect degradation. Chesson and Orskov (1984) observed that chewing by the animal and methods of feed preparation which maximize damage (like chopping and grinding) promote colonisation and have a marked effect on rates, if not on the ultimate extent, of degradation.

CHAPTER SIX

EXPERIMENT FOUR

THE POTENTIAL OF UREA-AMMONIATED RICE STRAW FOR DRY SEASON FEEDING OF SHEEP IN GHANA

6.1 INTRODUCTION

The unavailability of good quality forage, especially during the dry season, as a major constraint to livestock production in the tropics, and in Ghana for that matter, has been well documented (Rose-Innes, 1960, Larsen and Amaning-Kwarteng, 1976, Alhassan and Aliyu, 1991, Amaning-Kwarteng, 1991). Growth of ruminants, during the dry season is represented by a sawtooth curve (Rose Innes, 1960) and on the Accra plains, Rose Innes (1960) estimated weight loss in cattle over the dry season to be 11% of body weight. De Leeuw (as cited by Alhassan and Aliyu (1991) put the weight loss as 15-20% in cattle in Northern Nigeria.

Many studies have been undertaken to devise means of overcoming the dry season feeding problem in Ghana by the use of crop residues and agro-industrial by-products (Larsen and Amaning-Kwarteng, 1976, Addae, 1988, Amaning-Kwarteng, 1991). Amaning-Kwarteng <u>et al</u> (1986) reported that NaOH - treated straw diets provided more energy than required for maintenance for sheep and cattle in that the animals consumed over 1.5 times metabolizable energy relative to their respective maintenance requirements. Alhassan and Aliyu (1991) have also found that urea-ammoniation significantly increased intake of maize stover by cattle even though the diets did not prevent cattle weight loss.

The objective of this experiment was to quantify the potential of urea-ammoniated rice straw in reducing dry-season weight loss by calculating ME consumption by the sheep relative to their maintenance requirement.

6.2 MATERIALS AND METHODS

6.2.1 Animals and management

Six Nungua Black Head x Djallonke wethers weighing about 20kg live-weight were used. Three of the sheep were "intact" and housed in individual pens in an open-sided shed with elevated concrete flooring. The remaining 3 sheep were fitted with permanent rumen cannulae (6.4cm diameter) and housed in individual metabolism cages.

Two weeks prior to the commencement of the experiment the sheep were injected with a suspension supplying vitamins A, D and E and treated for both ecto - and endoparasites. All animals were weighed at the beginning and end of each period and the individual mean body weight for each period used to scale the nutritional characteristics measured. Water was available to each animal _ad lib_.

6.2.2 Diets

Rice straw (local variety from Kpong Farms) was coarsely chopped (2-4cm pieces) and subjected to 3 separate treatments which constituted the three experimental diets/treatments, A, B and C.

Diet A: Straw was not treated with any chemical but sprayed with mineral solution which supplied (g/kg) 79 water, 14.2 urea

N, 1.0 S, 0.9 P and (mg/kg) 1.8 Cu and 0.11 Co. Limestone was then sprinkled on the straw to supply (g/kg) 1.0 Ca. The straw was not ensiled but kept in jute sacs for at least 7 days before feeding.

Diet B: Straw was sprayed with NaOH solution (45.6g NaOH in 113g water) followed by a mineral solution and limestone as for diet A. Straw was also not ensiled but stored as in diet A.

Diet C: Straw was spread in an earthern pit (1m x 1m x 1.25m) lined up with polythene sheets and each layer of 16kg straw sprayed with a urea solution (62.5g urea in 625ml water/kg straw). Each pit was filled with 112kg straw. Filled pits were covered with polythene sheets, followed by heaps of soil and left for 21 days before "excavating". Ensiled straw was aired for 24h sprayed with minerals as for diet A, before feeding. The mineral solution here was devoid of nitrogen.

6.2.3 Experimental design and feeding

Each of the 3 diets was offered to each sheep in a two 3 x 3 latin square design. Each period comprised 15 days adaptation followed by 7 days sample collection. Feed intakes were measured daily and 100g samples collected daily and bulked. Sub-samples were taken at end of trial and dried at 50°C for chemical analyses.

Total faeces were collected daily, into faecal bags attached to the sheep, and dried at 50°C. Dried samples were bulked for each animal over the collection period.

6.2.4 Chemical analysis

Feed, refusals and faeces samples were analysed for DM by drying in forced drought oven to a constant weight at

$50^{o}C$. OM was determined as DM less the residual ash obtained after ashing at $550^{o}C$ for 16h. N was analysed by micro-Kjeldehl technique. NDF and ADL were determined by the method of Goering and Van Soest (1970).

6.2.5 Statistical Analysis

Data were subjected to an analysis of variance for two 3 x 3 latin squares. Interactions between treatments and squares were not significant and effect of treatment was tested against residual mean square (4d.f.). Treatment means were compared on the basis of the least significant difference (Snedecor and Cochran, 1981).

6.3 RESULTS

The chemical composition of untreated rice straw and experimental diets is shown in Table 6.1. There was an improvement in the CP of all experimental diets over the untreated straw.

Table 6.2 shows the dry matter intake, organic matter digestibility and metabolizable energy intake of sheep fed the experimental diets. There was a significant ($P<0.05$) increase in rice straw intake 23.1 g/kg BW to 31.4g/kg BW as a result of treatment with urea. Organic matter digestibility also increased by 2.8 percentage units with urea ammoniation.

The metabolizable energy intake of urea ammoniated straw was higher than untreated straw but lower than NaOH treated straw.

Table 6.1: Chemical composition of Untreated rice straw and experimental diets A (sprayed with only mineral solution), B (treated with NaOH and sprayed with mineral solution and C (ensiled with Urea and then sprayed with Urea-N free mineral solution) (Values are means of three analyses per sample)

Chemical Component	Untreated Straw	Test Diets A	B	C
% Dry Matter (DM)	90.9	88.6	83.3	68.8
Composition on DM basis (%)				
Organic Matter	84.3	81.8	78.1	76.5
Crude protein	4.32	13.0	12.6	14.9
NDF	75.9	75.6	66.2	54.5
ADL	8.25	8.21	7.45	6.88

Table 6.2: Dry Matter (DM) intake, organic matter (OM) digestibility and metabolizable energy intake (MEI) relative to maintenance energy requirements (Mm) by sheep fed diets A, B and C*
(Values are means of five sheep per diet)

*Parameter	Diet			SE (4d.f.)
	A	B	C	
Mean live weight (kg)	19.9	20.1	20.0	
DM Intake (g/d)	46.0	71.9	62.8	20.6
(g/kg BW)	23.1	35.7	31.4	2.35
Apparent OM Digestibility (%)	53.8	60.3	56.6	0.82
DOMI (g/d)	20.2	33.9	27.2	12.6
DOMD (%)	43.9	47.2	43.4	3.15
MEI (MJ/d)	3.03	5.09	3.50	0.46
Mm (MJ/d)	3.79	3.81	3.80	0.63
MEI/Mm	0.80	1.34	0.92	0.081

DOMD = Digestible organic matter in dry matter.

MEI = Metabolizable energy intake

= DOMD x 0.15 x Dry matter intake (MAFF, 1975)

Mm = Maintenance energy requirement

= 1.2 + 0.13 BW (where BW is body weight in Kg. (MAFF, 1975).

DOMI = Digestible OM intake.

6.4 DISCUSSION

That NaOH - treated straw is able to support maintenance energy requirement has been reported by several workers (Jackson 1977, Kellaway *et al*., 1978, Amaning-Kwarteng, *et al*., 1986); Amaning-Kwarteng, 1991).

In the present study urea ammoniated straw could not provide all required maintenance energy but showed 15% improvement over the unensiled straw. In a similar study in Northern Nigeria Alhassan and Aliyu (1991) observed that urea-ammoniated maize straw could not prevent weight loss, however, the weight decline in animals consuming the treated straw was 15-20% smaller than observed for cattle in the ecological zone.

The present study suggests that with little supplementation, such as with leguminous shrubs (Amaning-Kwarteng, 1991) urea ensiled straw could supply maintenance needs of ruminants during the dry season.

CHAPTER 7

GENERAL DISCUSSION

Treatment conditions affecting urea ammoniation as discussed by Guessous et al (1989) are urea level, length of treatment, moisture content of straw, environmental temperature, urease activity and type and quality of material being treated.

The optimum urea level, moisture content and treatment time for ensiling straw in this study were found to be 6.5%, 40% and 21 days respectively at an ambient temperature of 28°C. These results are similar to those obtained by Guessous et al (1989) whose optimum conditions were 6% urea concentration at 30% moisture. Jayasuriya (1985) also recommended 4-5% urea concentration and treatment period of 3-4 weeks.

Contrary to these results however, Alhassan and Aliyu (1991) obtained optimum conditions to be 4% urea concentration and incubation period of 7 days. This disparity could be due to the difference in straw type used in both experiments; while rice straw was used in the present study, Alhassan and Aliyu (1991) used maize straw. Table 2.2 and 2.3 show differences in composition between straw types which could account for the differences in optimum conditions for ammoniation.

The optimum values obtained in this study were used to ensile rice straw for nylon bag degradability studies (Chapter 5) and Intake Digestibility Studies (Chapter 6).

Ensiling with urea in the above experiments increased dry matter disappearance and increased dry matter intake and digestibility of rice straw because the ligno-cellulosic bonds had already been loosened by the presence of ammonia from urea. This action therefore enhances the digestibility. Residual-N is also more effectively utilized with the greater availability of energy in the ensiled material.

Even though the equation used in Chapter 6 is used under temperate conditions, it has been used here to estimate the potential of urea ammoniated straw as a maintenance diet. This meets the requirements of a maintenance feed given by Devendra (1985) as 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.

Where there's the need to turn over animals for marketting, urea ammoniated rice straw could be used as an ideal basal diet with some amount of dietary supplementation to provide extra energy and bypass protein.

CHAPTER 8

CONCLUSION

The optimum conditions required to ensile rice straw with urea in Southern Ghana are 6.5% urea concentration, with 40% moisture content and stored for 21 days.

Rice straw treated this way changed it from a poor quality feed to a medium quality, which has the potential to maintain liveweight of sheep.

The type of silo to be used is determined by how much the individual farmer can afford.

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APPENDIX 1

Calculation of amounts of urea and water added to straw in Experiment 1

A. **Moisture level**

DM content of air dry straw = 86.4%

$\therefore$ moisture content of straw = 13.54%

To raise this to 40% moisture level,

$$\frac{40}{100} = \frac{135.4 + x}{1000 + x} \quad \text{i.e. per kg}$$

$$4(1000 + x) = 10(135.4 + x)$$
$$6x = 2646$$
$$x = 441\text{cm}^3/\text{kg straw}$$

ii. 50% moisture level

$$\frac{50}{100} = \frac{135.4 + x}{1000 + x}$$

$$5000 + 5x = 1354 + 10x$$
$$5x = 3646$$
$$x = 729.2\text{cm}^3/\text{kg straw}$$

iii. 60% moisture level

$$\frac{60}{100} = \frac{135.4 + x}{1000 + x}$$

$$4x = 4646$$
$$x = 1161.5\text{cm}^3/\text{kg straw}$$

B. **Urea concentration**

i) 3.5% urea
DM of straw = 0.8646

$$\frac{3.5}{100} \times \frac{1000}{0.8646} = 40.48\text{g urea/kg straw}$$

ii) 5.0% urea

$$5/100 \times \frac{1000}{0.8646} = 57.83\text{g urea/kg straw}$$

iii) <u>6.5% urea</u>

$$\frac{6.5}{100} \times \frac{1000}{0.8646} = 75.15\text{g urea/kg straw}$$

iv) <u>8.0% urea</u>

$$8/100 \times \frac{1000}{0.8646} = 92.53\text{g urea/kg straw}$$

APPENDIX II

SUMMARY OF ANOVA FOR VARIOUS PARAMETERS STUDIED IN EXPERIMENT 1

Source	df	N_2	M/S				PROBABILITY				
			NDF	ADF	Hemicell.	IVOMD	N_2	NDF	ADF	Hemicell.	IVOMD
TIME (A)	2	0.11	1.30	2.01	3.35	2.36	0.18	0.43	0.21	0.31	0.01
UREA (B)	3	0.02	4.27	1.69	0.75	2.24	0.04	0.07	0.27	0.83	0.01
MOIST (C)	2	0.05	0.22	1.62	2.28	1.69	0.03	0.85	0.28	0.43	0.03
A x B	6	0.003	3.00	2.11	3.54	2.25	0.76	0.13	0.17	0.30	0.53
B x C	4	0.006	0.36	0.27	1.56	2.76	0.38	0.95	0.91	0.72	0.40
A x C	6	0.17	0.92	1.58	1.77	3.01	0.05	0.64	0.29	0.61	0.37
A x B x C	12	0.05	1.4	1.14	2.59	2.53					
TOTAL	35										

APPENDIX III

SUMMARY OF ANOVA FOR VARIOUS PARAMETERS TESTED IN EXPERIMENT 2

Source	df	N_2	M/S				PROBABILITY				
			NDF	ADF	Hemicell.	IVOMD	N_2	NDF	ADF	Hemicell.	IVOMD
Rep.	2	0.067	5.207	26.510	24.206	0.821	0.727	0.133	0.473	0.473	0.457
Silos	2	1.289	11.759	64.441	21.521	3.962	0.053	0.041	0.218	0.508	0.061
Error	4	0.193	1.491	28.220	26.718	0.918	0.011	0.109	0.011	0.041	0.240
TOTAL	8										