EVALUATION OF THE NUTRITIVE VALUE OF UREA-TREATED AND COTTON SEED CAKE SUPPLEMENTED WHEAT STRAW

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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ABSTRACT

Three experiments were conducted to determine the nutritive value of urea with urease enzyme treated; urea without urease enzyme treated and cotton seed cake supplemented wheat straw.

In experiment I, the effects of 0, 3 and 6% urea with urease enzyme treated wheat straw for 14 and 28 days, at 10 and 45% moisture levels on composition and digestibility were studied. Between 0 and 6% urea treatment CP, IVDMD and *in sacco* DM degradability of straw were increased ($P < 0.05$) from 6.4 to 8.9%; from 41.3 to 45.2%; and from 27.3 to 38.1%; while NDF, ADF, ADL and hemicellulose were reduced ($P < 0.05$) from 82.1 to 77.7%; from 57.6 to 56.0%; from 7.8 to 7.2%; and from 24.3 to 21.0%, respectively. When the moisture level was raised from 10 to 45%, CP and IVDMD were reduced ($P < 0.05$) by 1.4 and 3.1; and NDF, ADF and, ADL were increased ($P < 0.05$) by 1.5, 1.0 and 0.5 percentage units, respectively. Extending treatment time from 14 to 28 days improved ($P < 0.05$) the DM degradability of the straw.

In experiment II, the effect of CSC supplementation to urea without urease enzyme treated wheat straw on DMI and LWG by wether sheep was determined. When urea treated straw was fed the daily straw DMI and LWG of wether sheep were improved ($P < 0.05$) from 462.9 to 597.1 g; and from a loss of 15.2 g to a gain of 13.7 g, respectively. At 0, 100 and 200 g levels of

CSC supplementation, the total DMI and LWG were improved ($P < 0.05$) from 518.6 g to 644.3 g and 697.0g; and from a loss of 28.9 g to a loss of 1.7 and to a gain of 28.5 g, respectively. Urea treatment and CSC supplementation improved ($P < 0.05$) the DMI and LWG by wether sheep.

In experiment III, the effect of CSC supplementation to urea without urease enzyme treated wheat straw on In vivo digestibility was investigated. Urea treatment improved ($P < 0.05$) the digestibilities of DM, OM, CP, CF, NDF, hemicellulose and cellulose of straw by 5.1, 6.5, 38.9, 7.5, 7.5, 12.0 and 9.7 percentage units, respectively. Cottonseed cake supplementation improved the digestibility of the diet.

1. INTRODUCTION

Cattle raising, on the Central Ethiopan highlands, is complementary to crop production, is also geared to the maintenance of the existing 5 to 6 million oxen which are thought to be just adequate for the current draught power requirement for cultivation and transportation. Although cattle are the major capital of an Ethiopian farmer, and an important component of the national economy, the industry is still at undesirable stage of development. The yearly revenue generated from this sector of the economy is unproportional to the huge cattle population in the country (Ministry of Agriculture, 1985).

There are several inter-related and rather complicated problems identified for the country's livestock industry. The major ones are: poor financial and technical backing by the government; ineffective information feed-back between research centres, extension workers and farmers; high incidence of endemic livestock diseases; indiscriminate animal breeding systems and poor market outlets. The problems of cattle production are amplified further when animals are exposed to prolonged nutritional

stresses which are caused by social factors, seasonal variations in feed suply and drought.

Cattle population over the highlands is closely associated with high human population pressure and cultivation intensity. At present, most of the animals are kept by families with a farm size ranging from 1-2 ha, and the average animal holding per family is: 4.7 cattle, 3.8 sheep and 3.5 goats (Ministry of Agriculture, 1985). To feed the increasing human population more and more range and forest areas will, inevitably, be allocated to crop production. Cattle populations will also tend to increase correspondingly to meet the additional draught power requirements. Thus, the resulting net effect of the situation could be characterized by a decreased unit of grazing land per animal, leading to overgrazing, destruction of natural grasslands and natural forests and severe soil erosion.

Presently, farmers are not ready to accept such technologies as pasture development and forage conservation to avert the above mentioned environmental hazards. In fact, it is likely that the farmers will turn down outrightly such development schemes as they require more land and capital. On the other hand,

using crops as animal feed is impractical as the current crop production in the coutry is already on a subsistence level (Preston, 1972). The small amounts of concentrates from large scale food mills are mainly exported, and concentrates from small scale food mills are usually available for livestock feeding.

Agro-industrial by-products and low quality roughages, from mature grasses and crop residues, are considered as alternative feeds for ruminant animals. Information on Ethiopia's annual production of agro-industrial by-products and low quality roughages is not very well documented. However, from grain production figures it is not hard to imagine that there are enormous quantities of by-products produced which could be utilized more productively. According to Kossila (1984), under African farming conditions, the grain to straw ratio in wheat is 1:2.

During the long dry season, straw is about the only feed for most ruminant animals. But roughages such as straws and other highly lignified arable by-products are of low nutritive value, because of inherent low digestibility, and deficiencies of N and vitamins. Due to the low nutritive value of straw, total dry matter intake is below 2% body weight,

and the total energy and protein intake of animals on such diets are therefore insufficient for growth, reproduction and production (Jackson, 1981). Many chemicals and treatment methods have proved effective in improving digestibility and nutritive value of low-quality roughages. However, most of the chemicals studied are cost prohibitive and some are not safe to handle. From technological, cost and ease of treatment point of view, urea treatment is considered to fit relatively well to the condition of small holder farmers in developing countries. The active chemical in urea treatment is ammonia.

In Ethiopia urea treatment and oil seed cake supplementation are anticipated to be relatively simple and cheap techniques for improving the feeding value of wheat straw for ruminant animals. Wheat being the third most important grain crop will contribute substantially to the available crop by-products. Fertilizer grade urea can be procured from the local agricultural extension offices and oil seed cake from the many small scale oil seed processing plants.

This current study was, therefore, conducted with the following objectives:

1. to study the treatment effects of urea with urease enzyme on wheat straw and

their effects on:

a) chemical composition

b) *in vitro* dry matter digestibility (IVDMD)

and c) *in sacco* dry matter degradability.

2. to study the effects of urea without urease enzyme treatment and cotton seed cake supplementation of wheat straw on:

a) feed intake

b) live weight gain using wether sheep.

and c) *in vivo* dry matter, organic matter, crude protein, crude fiber, nuetral detergent fiber, acid detergent fiber, hemicellulose and cellulose digestibilities.

2. LITERATURE REVIEW

2.1 Availability and Extraction Rate of Agro-industrial By-products and Crop Residues

In the tropical regions of the world, there is a large amount of low-quality feedstuffs for ruminant animals from agro-industrial by-products, crop residues and mature grasses. Agro-industrial by-products from fruit and vegetable, tea, marine animals and animal processing factories; from sugar cane and oil extraction mills; from agro-forestry and coffee processing plants are available in substantial quantities. These agro-industrial by-products are considered to have high potential feeding value to ruminant animals, if they are properly utilized (O'Donovan, 1975; Jackson, 1977a; Devendra and Raghavan, 1978; Thomsen et al., 1978; Ranjhan, 1979; Preston, 1972; Rexen and Thomsen, 1976).

Several workers attempted to estimate the world's total annual production of crop residues. Kategile (1982) suggested that the total quantities of crop residues produced annually could be estimated from the total grain yield. Jackson (1977a) estimated the total annual production of world cereal straws and stovers to be 2 billion tons. According to Kossila (1984), the total

dry matter fibrous by-products obtained from cereal crops in the world for the year 1970 and 1981 were 3.3 and 4.4 billion tons, respectively.

Crop residues and agro-industrial by-products have been categorized as primary and secondary by-products or as energy, protein and mineral feeds on the basis of their nutrient contents. Devendra and Raghavan (1978) categorized them as:

a) Primary by-products - form the major portion of the ingredients of basal feed in ruminant feeding systems.
b) Secondary by-products - form the minor portion of ruminant feed (serve as supplements).

Ranjhan (1980), in a similar way, categorized them as:

a) Energy rich products - molasses and bananas
b) Protein rich products - oil seed cakes and fish meal
c) Mineral rich products - bone meal
d) Miscellanous by-products which supply both energy and protein, i.e. brewer's grains and yeast, fruits and vegetables

Extraction rate of some of the important crop residues and agro-industrial by-products, under Asian and Far East conditions, is illustrated by Table 2.1. As

Table 2.1: Major and Minor by-products from Various Sources with Approximate Extraction Rates in Asia and Far East (Devendra and Raghavan, 1978)

Item	Product	Extraction Rate (%)
Cotton	Cotton seed meal	40-45
Groundnut	Groundnut vines (stems & leaves)	41-57
	Groundnut meal	53-57
Sesame	Sesame Cake	60
Maize	Maize Bran	8-10
	Maize Germ Meal	16-18
	Maize Stover	38
	Maize Cobs	12
Rice	Broken Rice	4-5
	Rice Bran	10
	Rice Husk	15-17
	Rice Straw	100
Wheat	Bran	10
	Straw	100
Sweet Potatoe	Vines (stems & leaves)	24-35
Sugar cane	Bagasse	12-15
	Green tops	15-20
	Molasses	3-4
Tapioca	Tapioca waste	55-59
Mango	Kernel	50-55
Pineapple	Pineapple waste	60-80
Poultry	Poultry litter	26
Ruminant	Blood	0.6
	Meat and bone meal (dry)	25-30
	Rumen content (wet)	0.8

it can be seen from the table, the extraction rate of by-products from cotton seed and wheat were 40-45% and 100%, respectively.

2.2 Chemical Composition of Low Quality Roughages

Factors such as, species, variety, season, location and cultural practices are known to cause variations in chemical composition of low quality roughages (Nicholson, 1984). Low quality roughages are characterized by their high content of lignocellulose, low content of available carbohydrates (sugars, starch) and low contents of nitrogen, minerals (Ca, P) and vitamins (Theander, 1981). Jackson (1977a) reported that the protein content of low quality roughages ranges from 3 to 5%.

Cell wall material in low-quality roughages accounts for more than 60-80% on dry matter (DM) basis (Jackson, 1977b; Theander, 1981). There is a decrease in cell content and an increase in cell wall components as plants advance in age. This situation is explained by the translocation of protein and carbohydrates from stems and leaves to the seeds, thus forming more fibrous structural cell wall materials in the leaves and stems of the plants. The main components of cell wall fractions are holocellulose (Hemicellulose and cellulose), lignin, pectin, protein

(glucoprotein), silica, tannin, cutin and phytic acids (Theander, 1981).

The two important structural carbohydrate components of cell wall are cellulose and hemicellulose. Cellulose is crystalline, organized as micro-fibrils held in a matrix of largely amorphous, non-cellulose polysaccharide, lignin and some times glucoprotein. Cellulose is characterised by high mechanical strength and resistance to chemicals. In gramminae family xylan and hemicellulose are predominant. Acetyl groups in gramminae family are estimated to be 1-2% of the cell wall. Acetyl groups occur as a substitute of xylan on xylose units. Waite et al., (1964) cited by Theander (1981) showed that the degree of acetylization increases with the age of the plant.

Lignin, a three dimensional polymer built of phenyl-propane units, is an important component of the cell wall. Lignin and silica are associated with the cell wall polysaccharides and thus contribute to the structural rigidity of the plant. Both lignin and silica inhibit digestion of cell wall by rumen micro-organism and their enzymes. Cutins are indigestible but they do not inhibit digestion of cell wall in the rumen (Theander, 1981).

2.3 Utilization and Nutritive Value of Crop Residues

Utilization of by-products differs from region to region. In the developing countries of tropical regions, crop residues form the major part in the daily diets of almost all ruminant animals, particularly during the long dry season. In a few intensive livestock industries crop residues are used as feed extenders. Countries which are repeatedly affected by severe and prolonged drought use crop residues as survival feeds for their ruminant animals. However, not all by-products are assigned to ruminant animal feeding; but may have alternative uses in factories. Straw, for example, is used in paper and paper board production, and molasses in tobacco processing and alcohol production factories.

Crop residues are bulky, of low feeding value to animals and under some conditions transportation and storage costs involved are considered to be high and uneconomical, and hence these are either ploughed into the soil or burnt on the farm. This practice, apart from causing air pollution, is a waste of substantial quantities of potential energy which could be equal to the amount of energy contained in the grain yield (Jackson, 1977 a).

Farmers in some developing countries use both straw and animal dung as fuel which results in a wastage of the protein contained therein. On the other hand, energy would be wasted if animal dung is used as a soil fertilizer. Therefore, the best way of maximizing the utility of crop residue might be by feeding crop residues to animals, and by using the resultant dung as soil fertilizer after extracting the gas for fuel whenever possible.

Straw is an energy feed with a digestibility coefficient of 40-50% (Jackson, 1977a; MAFF, 1975). Royal Danish Farming Society estimated the Scandinavian Feed Units (SFU) of straw as 25.2 SFU/100 kg and that of barley grain as 101 SFU/100 kg.

Voluntary intake of straw by ruminant animals is so low that the daily total energy intake is not more than 100 kcal/kg$W^{0.75}$, which is just about enough for maintenance (Jackson, 1977b). Normally, cattle are considered to consume a maximum of 2% body weight on a coarse roughage like straw (Jackson, 1977b). However, the minimum intake required for maintenance is 2.5% body weight or 90 g/kg$W^{0.75}$ (Ørskov, 1981).

The feeding value of straw is low due to its low digestibility and low voluntary intake which is aggravated by a high content of lignin, silica and its deficiency in

important nutrients such as protein, minerals and vitamins, and by its bulky physical character. Horton et al. (1982) reported that low digestibility and poor nutrient composition are the factors limiting the utilization of straw by ruminant animals. In general, the feeding value of crop residues is influenced by factors such as, species, varieties, soil fertility, stage of maturity, method of collection, method of storage, and treatment method (Coxworth et al., 1981).

It is a well documented fact that digestibility, intake, energy yield and utilization of straw by ruminant animals could be improved by treatment. Jackson (1977b) stated that any treatment that could increase the energy yield of straws and stovers even by 10-20% would add tremendously to the world's livestock feed resources.

2.4 Supplementation

Low quality roughages are high in cell wall and low in soluble cell content, protein, minerals (Ca, P) and fat soluble vitamins (A and D). The main energy providing nutrients in poor quality roughages are cellulose and hemicellulose, which are fermented in the rumen by micro-organisms. Digestibility and animal intake from low quality roughages are low because of their failure to provide the rumen micro-organism and host animals with all nutrient

requirements. Thus adequate nitrogen and limited amounts of readily available carbohydrates are essential to maintain maximum animal intake and optimum fibre digesting activity of rumen micro-organisms (Anderson, 1978).

Mature draught animals appear to maintain low body condition and work satisfactorily on straw alone. Other productive animals fed on low quality roughages must be given additional good quality concentrates to balance the ration, so as to improve digestibility, intake and utilization of the diet (El-Shazly and Naga, 1981; Pigden, 1981; Theander, 1981; Nicholson, 1984; Preston and Leng, 1984; Verma and Jackson, 1984).

2.5 Treatment Methods of Low Quality Roughages

For more than a century scientists have been searching for methods of improving digestibility and hence the nutritive value of straw and other low quality roughages (Homb, 1948; Rexen and Thomsen, 1976; Jackson, 1977b; Devendra and Raghavan, 1978). The methods that have been investigated with varying degrees of success include physical, biological and chemical treatment. The current review will put emphasis on chemical treatment with only a brief mention of the former two.

2.5.1 Physical Treatment

Dry matter intake (DMI) by ruminant animals on low quality roughages can be affected by the physical character of the roughages and can be modified by mechanical comminution. Reduction of particle size of roughages by chopping, grinding and/or pelleting increases surface area and density, reduces time and energy required for the digested particles to pass through the digestive tract and hence increases voluntary intake with subsequent decrease in digestibility (Balch and Campling, 1962; Minson, 1963; Moore, 1964; Pigden and Bender, 1972; Horton et al., 1982).

Other physical treatment methods are soaking (Ranjhan, 1979; 1980), irradiation (Pigden and Heaney, 1969) and high pressure/high temperature steam treatment (Oji and Mowat, 1979; Knipfel et al., 1981). Soaking of straw in water for 1-2 hours removed oxalates with a subsequent improvement in voluntary intake (Ranjhan, 1979; 1980). Irradiation and high pressure/high temperature steam treatment appear to be infeasible both at the farm and commercial levels because of the equipment required (Jackson, 1978).

2.5.2 Biological Treatment

Biological treatment is based on the use of bacteria and fungi to improve the nutritive value of low quality roughages. In plant residues treated with white-rot fungi, lignin was degraded more than cellulose and *in vitro* digestibility was increased to 77% (Jackson, 1978; Zadrazil, 1984).

2.5.3 Chemical Treatment

It is a well established fact that chemical treatment increases digestibility, intake and utilization of low quality roughages. However, chemical treatment is justifiable when the value of the improvement is higher than the cost of treatment (El-Shazly and Naga, 1981). In the following sections chemicals used, methods of chemical treatment, factors influencing the effectiveness of chemical treatment, effect of chemical treatment on nutritive value of low quality roughages are reviewed.

2.5.3.1 Chemicals Used For Treatment

About 34 chemicals have been tested and their potential to improve the nutritive value of low quality roughages confirmed. The chemicals are grouped as alkali, acids,

salts, oxidizing agents, sulfur compounds and surfactants (Owen et al., 1984).

The 'ideal' character and practical usefulness of chemicals used for treatment were reviewed by Owen et al. (1984) and Verma (1981). Chemicals used for treatement should be locally available, cheap and safe to handle. The treatment method and equipments involved should be simple which require low volume of water and energy. Environmental pollution hazards and the residual ill-effects on the animal should be considered. It is also important to consider the preserving capacity and their potential as upgrading agents.

Of all the chemicals NaOH, an alkali, has been used often for treating low-quality roughages (Homb, 1948; Jones and Klopfenstein, 1967). Rexen and Thomsen (1976) from a comparison experiment of NaOH plus Na_2SO_3 and NaOH alone treated straw reported that digestibility of NaOH alone treated straw was higher. The effectiveness of hydroxides such as NaOH, $Ca(OH)_2$, NH_4OH and their combinations for treating low quality roughages have been studied extensively (Waller and Klopfenstein, 1975; Sundstøl et al., 1979; Saadullah et al., 1981b). Gharib et al. (1975) reported satisfactory results after treating low quality roughage with NaOH, NaOH plus S, Na_2S, Na_2SO_3, Na_2SO_3 plus Na_2CO_3, CaO, CaO plus NaOH, NaClO, $NaClO_2$.

Jackson (1978) reviewed the satisfactory treatment of poor roughages by NaOH, $Ca(OH)_2$ and NH_3. Sundstøl (1981b) stated that NaOH, Magadi soda, KOH, NH_4OH, NH_3 and urea are effective agents for poor roughages treatment.

Another commonly used chemical for roughages treatment is ammonia. Sources of ammonia for roughage treatment are NH_3 (gas), NH_4OH (liquid) and urea. Saadullah et al. (1980) and Chowdhurry (1981) reported that animal urine could also be used as a source of NH_3 for roughage treatment, provided safe methods for collection are developed to control the health risks involved. Effect of ammonia treatment on the feeding value of roughages has been studied (Waiss et al., 1972; Arnason and Mo, 1977; Sundstøl et al., 1978; Borhami et al., 1982). Saadullah et al. (1981a) treated rice straw with urea at village level using locally available and cheap materials, and they reported higher feeding value for the treated straws. Verma (1981) also reported an improved nutritive value of rice straw treated with urea and lime plus urea.

Other chemicals that have been used successfully to improve the nutritive value of poor quality roughages are chlorine compounds, chlorine gas and hydrogen peroxide, sodium formate (Chandra and Jackson, 1971), and lime (Verma, 1981).

2.5.3.2 Chemical Treatment Methods

2.5.3.2.1 Wet Treatment

The original Beckman method and its modification are known as wet method of roughage treatment. In the Beckman method, roughage is soaked in 1.5% solution of NaOH for 24 hours and washed with 40-50 litres of water per kilogram of the roughage.

However, the original Beckman method has associated environmental pollution, requires large volumes of water for washing out lye, has high operational cost and results in loss of DM through leaching. Therefore, to avoid the draw-backs observed with the original Beckman method, it was modified by closed methods of Torgrimsby's recirculation, Boliden and Dip treatment methods (Homb, 1948; Jackson, 1978; Kategile, 1981; Kategile et al., 1981; Saadullah et al., 1981b; Sundstøl, 1981b; Homb, 1984).

2.5.3.2.2 Spraying

Spraying is a dry treatment method which involves an application of a strong chemical solution to poor roughages, mixing and keeping for a short reaction time

before feeding to animals. Several developments to spray treatment such as, daily spray, bulk treatment, farm scale mechanical treatment, and industrial processings have been developed (Rexen et al., 1975; Rexen and Thomsen, 1976; Jackson, 1977a; Jackson, 1978; Pirie and Greenhalgh, 1978; Wilkinson and Gonzalez, 1978; Barber et al., 1979; Coombe et al, 1979; Kategile, 1981; Sundstøl, 1981b; Rexen and Knudsen, 1984; Wilkinson, 1984a).

2.5.3.2.3 Stacking

The procedure and material requirements of stacking have been described by Sundstøl (1981b) and deals mainly with NH_3 treatment of straw. One of the first systematic experiments with NH_3 treated straw was conducted in Germany (Kronberger, 1933, cited by Sundstøl and Coxworth, 1984) and ever since many experiments have been conducted in different countries.

The advantages of NH_3 treatment were increased total nitrogen, the preservation and upgrading of the digestibility of high fiber by-products and the absence of residual ill-effects on the feeding andimals. The need for gas containers, irregular supply and high cost of NH_3, air pollution, and dangers involved in handling ammonia gas are the disadvantages observed (Zafren, 1959; Chomnyszyn et al., 1960; Arnason, 1976; Arnasan and Mo, 1977; Kernan et al., 1977; Sundstøl et al., 1978 and

Coxworth, 1984).

2.5.3.2.4 Ensiling

In the context of chemical treatment of low quality roughage, ensiling means the storage of treated roughages in a silo. The general principles of ensiling, physical and chemical changes occuring in the ensiled roughage and its subsequent effects on the nutritive value of the material were reviewed by Wilkinson (1984b). The effectiveness of ensiling of treated roughages was reported by Jackson (1978) and Kategile (1981).

2.6 Factors Influencing the Effectiveness of chemical Treatment.

Chemical treatment of low-quality roughages is influenced by such factors as, type of roughage, chemicals used, temperature, treatment time, moisture, pressure and physical forms of roughage (Westgaard, 1981).

2.6.1 Type of Roughages

Roughages with very low initial digestibility and/or with high initial digestibility were not significantly affected by chemical

treatments. Beneficial chemical treatment effects were realized with roughages of an initial digestibility ranging from 40-60% (Waiss et al., 1972; Jackson, 1977b; Said, 1981; Tubei and Said, 1981).

Some roughages like lucerne stem have been reported to be chemically resistant to alkali (Rexen and Knudsen, 1984). Van Soest (1964) observed that lignin in grass was more soluble in alkali than lignin in legumes.

2.6.2 Chemicals Used

The effect of NaOH was reported to be highest compared to other chemicals used for treating low quality roughages. Although good treatment effects with other chemicals such as chlorine gas and peroxides were reported, they are less popular because of the high cost involved and the associated problems with the application methods (Jackson, 1977b).

Calcium hydroxide was reported to be least effective in treating low-quality roughages when compared to NaOH and KOH (Sundstøl et al., 1979; Garmo, 1981; Saadullah et al., 1981b). However, Gharib et al. (1975) observed that the effect of calcium hydroxide was equal to that of NaOH with a longer treatment time of more than 150 days. Ammonia gas

has a lower treatment effect compared to NaOH. But NH_3 gas treatment was observed to be more effective than aqueous NH_3, urea and animal urine. The effectiveness of aqueous NH_3 , urea, and animal urine treatment decreases in that order (Saadullah et al., 1981b; Westgaard, 1981).

2.6.3 Chemical Concentration, Temperature, Treatment Time, Pressure and Moisture

Conditions for chemical reaction to occur between a roughage and a chemical are, concentration of the chemicals, temperature, exposure time, pressure and moisture. Lower cell wall constituents were reported by treating straw with an increasing level of lye dosage (Rexen and Thomsen, 1976).

Sundstøl et al. (1979) reported higher in vitro dry matter digestibility (IVDMD) of straw treated at 5.4% NaOH level compared to 2.7% NaOH treated and untreated straw. In vitro dry matter digestibility of treated straw increased linearly with increasing levels of chemical concentration (Westgaard, 1981; Kristensen et al., 1978, cited by Rexen and Knudsen, 1984). Jackson (1977b) reviewed IVDMD of straw treated with alkali concentration up to a level of 12-15% NaOH. He reported that IVDMD increased linearly up to 10% NaOH level of treatment and levelled off thereafter. Rexen and Thomsen (1976) also reported an increase of in vivo organic matter digestibility of straw treated with increasing NaOH concentration up to 4-5%. Similarly, Westgaard (1981) reviewed several

experiments and reported a linear increase in *in vivo* DMD of NaOH treated straw with increasing levels of alkali up to 8-10%.

Temperature, pressure and treatment time were influencing the speed and duration of chemical reaction between straw and NaOH (Sundstøl *et al.*, 1979; Westgaard, 1981; Rexen and Knudsen, 1984). In the pelleting process, high pressure and temperature increased the effectiveness of chemical treatment (Jackson, 1977b). Sundstøl *et al.* (1979) ensiled NaOH treated straw under a modest pressure of 60 g/cm^2. They observed a slight increase in IVDMD. They concluded that this increased digestibility could be explained by the increased surface area of contact between straw and chemical due to pressure. Westgaard (1981), however, reported that the influence of pressure above 50 atmosphere was small.

Ololade *et al.* (1970) studied the effect of temperature on the effectiveness of NaOH treatment of straw. They suggested that the same treatment effect could be obtained at lower temperature either by increasing chemical concentration or treatment time.

Sundstøl *et al.* (1979) studied the effect of treatment time using NaOH treated straw. Straw was treated with 2.7%

and 5.4% NaOH and ensiled for 3 hours and for 9 weeks. In vitro DMD were 39.2, 55.5% for 2.7% NaOH and 49.5, 72.7% for 5.4% NaOH treated straws, respectively.

The volume of solution used for roughage treatment depends on the initial moisture content of the roughage (Westgaard, 1981). Sundstøl et al. (1979) investigated the effect of moisture during treatment on digestibility of roughages. Straws at two moisture levels of 17% and 51% were treated with NaOH and ensiled. They observed a negative effect on IVDMD by increasing the moisture content of the straw from 17% to 51%.

However, in a spray treatment method better treatement effects were realized by using larger volume of alkali solution for treating roughages than with a small volume (Sundstøl et al., 1979). For effective treatment, thorough mixing of alkali solution and straw was believed to be more vital than the chemical concentration. Therefore, no beneficial effect was gained by increasing the volume of chemical solution above the level enough for thorough mixing (Jackson, 1978; Sundstøl et al., 1979).

2.7 Effect of Chemical Treatment on Chemical Composition and Digestibility of Low Quality Roughages

The beneficial treatment effects of the various chemicals on the chemical compositions and digestibilities of low quality roughages have been investigated extensively (Waiss et al., 1972; Jackson, 1977a; Saadullah et al., 1980; Garmo, 1981; Hossain and Rahman, 1981; Mehrez et al., 1981; Sundstøl, 1981b; Theander, 1981; Nangole et al., 1983; Wanapat et al., 1985).

2.7.1 Effect of Chemical Treatment on Chemical Composition

Chemical was suggested to react with straw (Jackson, 1977b; Theander, 1981). Jackson (1977b) suggested that NaOH might have reacted chemically with roughages, after he observed that some of the added NaOH was not recovered. The main effects of chemicals are disruption of the cell walls by dissolving out hemicellulose, lignin and silica, by hydrolyzing ammonic and acetic acid esters and causing the swelling of cellulose. Surface area of the cell wall is increased. Cellulose is rendered less crystalline, more swollen and free of factors that could inhibit enzymatic hydrolysis in the rumen (Theander, 1981).

Effects of chemical treatments on the chemical composition of roughages were studied by several workers. Mehrez et al (1981) treated rice straw and maize stalk with NaOH and observed a loss of DM of 15.7 and 12.4%; and a loss of OM of 13.6 and 12.5%, respectively. Sodium hydroxide (NaOH) spray treatment of rice straw and maize stalk, resulted in DM and OM loss of 1.8, 1.3% and 6.1, 3.9%, respectively (Mehrez et al., 1981). Haque et al. (1981) observed no effect on DM content of straw due to lime treatemnt.

Ash and crude fibre contents were increased; DM and cellular contents (crude protein, ether extracts, nitrogen free extracts) of straw were decreased by caustic soda treatment (Jayasuriya et al., 1981; Musimba, 1981; Nangole et al., 1983). Rexen and Thomsen (1976) observed higher contents of ADF after washing alkali treated straw and suggested that what was lost during washing consisted of hemicellulose. Whistler and Teng (1970) suggested, that apart from swelling, there was no effect on the cellulose as a result of alkali treatment. Rexen and Thomsen (1976) reported a reduction in the cell wall constituents and no change in acid detergent fiber (ADF) and lignin fraction of cell wall by increasing lye dosage.

The effect of NH_3 treatment on the chemical composition of straw was studied by Sundstøl et al. (1978), Waagepeterson and Thomsen (1977) and Borhami et al. (1982).

Waagepeterson and Thomsen (1977) reported a reduction in crude fibre while Sundstøl et al. (1978) observed an increase of nitrogen content of the straw by 0.8-1.0 percentage units due to NH_3 treatment. Borhami et al. (1982) also reported an increase of nitrogen due to NH_3 treatment; nitrogen was further increased when NH_3 treated straw was sprayed with organic acids.

In an experiment with urine treated rice straw, Saadullah et al. (1980) reported a lower DM content, a reduction in crude fibre by 5 percentage units, and an increase in CP from 3.3% to 5.6%.

The effect of urea treatment on chemical composition of straw has been studied by several workers. Hossain and Rahman (1981) from an experiment with urea treated rice straw reported 100% increase in CP, and a reduction in crude fibre by 2.5%. Saadullah et al. (1981a) using 0, 3 and 5% urea treated rice straw reported a protein content of 2.9%, 5.9% and 6.7%, respectively. In another similar experiment, Saadullah et al. (1981c) reported a reduction of DM by 2-4 percentage units, and an increase of CP by a factor of 2-2.5 due to urea treatment of rice straw.

2.7.2 Effect of Chemical Treatment on Digestibility

The effect of chemical treatment on digestibility of roughages has been investigated widely. Jackson (1977b), in a digestibility experiment with Beckman treated straw reported an increaseof *in vivo* DM digestibility from 40 to 70% and in IVDMD from 40 to 80%. Jackson (1978) reported that the digestibility of straws whose initial digestibilities ranged from 35-55% could be increased by 10-20 percentage units depending upon the method of treatment used.

Chemical treatment of straw improved DM, organic matter, crude fiber and carbohydrate digestibilities (Chaturvedi *et al.*, 1973). Saadullah *et al.* (1981c) treated rice straw with 4% NaOH, and 3% NaOH plus 1% lime. Dry matter digestibilities were 44.7% for untreated, 60% for 4% NaOH and 72% for 3% NaOH plus 1% lime treated rice straws.

Nangole *et al.* (1983) studied the effect of NaOH and Magadi soda treatment on the digestibility of maize cobs. Dry matter digestibility (DMD) of maize cobs was improved by 9.5 and 16.9 percentage units due to NaOH and Magadi soda treatment, respectively. Digestibility of cell wall, cellulose and crude proten (CP) was higher for Magadi soda treated maize cobs.

Organic matter digestibility (OMD) in Beckman treated straw was increased by 22 percentage units (Garmo, 1981). Kristensen (1981) reported that Beckman treatment improved OMD by 15-22 percentage units, and 80% of neutral detergent fiber (NDF) was rendered digestible.

Digestibility of ensiled straw treated with various alkalis were studied by Garmo (1981). He reported significant improvements in _in vivo_ OMD and enzyme soluble OM due to treatment.

Improved digestibility of straw due to NH_3 treatment has been reported by many workers. Organic matter digestibility (ODM) of NH_3-treated straw was improved by 10-15 percentage units when compared to untreated straw (Sundstøl _et al._, 1978; Sundstøl, 1981b). Abidin and Kempton (1981) from a digestibility experiment with NH_3-treated straw reported that IVDMD was improved by 8 percentage units.

Tubei and Said (1981) conducted an experiment to study the effect of NH_3 treatment on the utilization of maize cobs and maize stover by sheep in Kenya. Ammonia treatment increased DMD of maize cobs by 6.2 percentage

units and that of maize stover by 2.8 percentage units. Crude fibre digestibility of NH_3-treated maize stover was 4.8 percentage units higher compared to that of untreated maize stover. The digestibility coefficients of NDF, NFE, EE in both maize cobs and maize stover were significantly improved by NH_3 treatment.

Animal urine and fertilizer urea as cheap sources of NH_3 for roughage treatment have attracted the attention of many workers. In studies with animal urine treated rice straw, DMD, OMD, and crude fiber digestibility were observed to be higher by 13-15, 10 and 6-9 percentage units, respectively. Nitrogen retention was also improved from -2.94 (untreated) to -1.15% (treated straw), an improvement of 1.79 percentage units (Saadullah et al., 1980; Saadullah et al., 1981a).

Urea treatment of low quality roughages has also been shown to bring about similar improvements in digestibility. The DMD, CPD, and CFD of rice straw was improved by 30, 20 and 10%, respectively (Hossain and Rahman, 1981). Dolberg et al. (1981a) similarly observed an increase of DMD by 13 percentage units due to urea treatment. Saadullah et al. (1981a) used 0, 3 and 5% urea on rice straw ensiled in earthen pits. The OMD and CFD were 45 and 56%; 54 and 55%; 56 and 60% for the three levels of

urea treatment, respectively; OMD and CFD for 5% urea treated rice straw ensiled in bamboo baskets were 56 and 64%, respectively. Similarly Wanapat et al. (1985) used urea treated and ensiled rice straw and observed higher ADFD and DMD in the treated straw.

Sundstøl (1981b) summarised the effect of alkali treatment using different treatment methods on OMD of wheat straw as follows:

Untreated	45%
Dip treatment (NaOH)	66-70%
Ensiled (NaOH)	60-65%
Spray (NaOH)	60-65%
Stacking (NH_3)	55-60%

2.8 Performance of Ruminant Animals fed on chemically treated and Protein Supplemented Crop Residues.

A large number of production experiments have been conducted to study the effects of chemical treatment and protein supplementation of crop residue on intake, performance and feed utilization by ruminant animals. In almost all of the studies beneficial effects of chemical treatment and protein supplementation on the feeding potential of crop residues were reported

(Preston, 1972; Sharma et al., 1972; Kishan et al., 1973; Jackson, 1978; Abidin and Kempton, 1981; El-Shazly and Naga, 1981; Kristensen, 1981; Said, 1981; Kategile, 1982; Arnaldo and Douro, 1983; Nabaweya et al., 1983; Nangole et al., 1983; Smith et al., 1983).

2.8.1 Effect of Chemical Treatment of Crop Residues on Dry Matter Intake (DMI), Live Weight Change and Feed Utilization by Ruminant Animals

Effects of chemical treatment of roughages on animal performance have been studied extensively in many production experiments with encouraging results. Nangole et al. (1983) compared the performance of grazing Friesian cattle supplemented with NaOH and Magadi soda treated maize cobs. Better performance in live weight gain was observed with cattle supplemented with NaOH-treated maize cobs than those on Magadi soda treated.

Waller and Klopfenstein (1975) in a production experiment compared NaOH, $Ca(OH)_2$ and NH_4OH treated straws. Animals on NaOH treated straws gained more weight than animals on $Ca(OH)_2$ or NH_4OH treated straws. Garmo (1981) from a comparison study with Beckman, dry and NH_3 treated straw for lactating dairy cows, reported that neither dry nor NH_3-treated straws gave as high net energy values as the Beckman method treated straws.

The feeding potential of untreated, 5% urea, 4% lime and 3% NaOH plus 1% lime treated straws were compared in a production experiment with calves. Calves were offered the treatment diets ad libitum. Compared to untreated straw, 3% NaOH plus 1% lime, and 5% urea treated straws were utilized better by 72% and 63.5%, respectively. In the same experiment utilization of untreated straw was improved by 52% when supplemented with urea (Saadullah et al., 1981b).

Horton et al. (1982) reported a production experiment with NaOH, NH_3 treated and pelleted straws. In all the experiments, they reported that treatment improved feed intake, weight gain and utilization of straw by animals. No additional benefit in animal performance was observed when NH_3 treated straw was treated again with NaOH. Solaiman et al. (1983) in a similar experiment reported that feed intake by sheep on NaOH, urea and NaOH plus urea treated water hyacinth was improved by 41.2%, 9.7% and 31.8%, respectively.

The effect of NH_3 on the feeding value of straw to ruminant animals has been investigated widely. Arnason (1976) undertook production experiments to evaluate the feeding potential of NH_3 treated straws to heifers, finishing bulls, steers and lactating dairy cows. Replacing 3kg hay

with treated straw resulted in 18.05% lower daily body weight gain in bulls compared to those on control diet of standard ration, but finishing bulls and steers on ammonia treated straw gained 25.33% and 25.53% more weight, respectively, than those on untreated straws. Intake from the treated straw by lactating cows was observed to be rather low compared to grass silage and good hay. Sundstøl (1981a) suggested that NH_3-treated straw could have good feeding potential to growing steers, if supplemented with minerals and vitamins.

Tubei and Said (1981) in a feeding experiment reported increased dry matter intake, organic matter intake and daily body weight gain by intact weaner Dorper male sheep fed NH_3-treated maize stover and maize cobs. In a feeding experiment with calves, the effectiveness of various alkali treatment methods for rice straw were tested. Saadullah et al. (1981b) fed calves on untreated, 5% urea, 4% lime and 3% NaOH plus 1% lime treated rice straws. Except in the untreated straws, diets of all groups were made isonitrogenous (8% CP) with urea supplement and sodium sulphate ($NaSO_3$) was added to give the N:S ratio of 10:1. Utilization of the treated straw was improved by 63.49%, 65.20% and 72.00%, respectively, by calves on 5% urea, 4% lime and 3% NaOH plus 1% lime treatment compared to those on untreated straws.

Technical feasibility of using indigenous available materials for storage of treated rice straw was studied (Dolberg et al., 1981b). The storage methods investigated were earthen pits, stacking and bamboo basket. The five treatment diets were untreated, 3% urea (stacked), 5% urea (earthen pits), 5% urea (earthen pits plus 10% molasses), 5% urea (bamboo basket) treated rice straws. Treatment diets were fed ad libitum to the experimental male sheep. Total daily DMI by the sheep from untreated, stacked, earthen pits, earthen pits plus 10% molasses, bamboo basket treated straws on g/kg $W^{0.75}$ basis, were 52.1, 57.5, 69.1, 71.5 and 62.9, respectively. It was suggested that indigenous materials could be used effectively to store urea treated straw. The untreated straw and 5% urea treated straw stored in bamboo basket were also fed to bullocks and improvements of 36% and 66.70% in DMI and LWG, respectively, for animals on treated straw were reported.

In a production experiment, the feeding potential of rice straw treated with urea and stored in bamboo basket for seven days were evaluated using lactating local and cross-bred cows (Khan and Davis, 1981). The treated and untreated straws were fed to the cows ad libitum with supplements of 2 kg of fresh Napier grass/cow, 500 g rice bran/cow, mineral mixture of 100 g/cow and 200g of oil seed cake/litre of milk produced per cow. Urea treatment

improved DMI by 96.2%, live weight gain by 173.2% and milk production by 111.0% when compared to cows on untreated straw.

2.8.2 Effect of Nitrogen Supplementation on Nutritive Value of Low Quality Roughages

Available nitrogen in the rumen, for microbial lignocellulosic breakdown, comes from the diet and from the host animal. The latter as recycling blood urea entering the rumen via parotid salivary gland and through rumen wall. Ruminants are, therefore, able to maintain adequate levels of rumen NH_3-N to facilitate microbial digestion on lignocellulose of roughage for a short feeding period of a few days. The subsequent decrease in intake by animals fed on poor roughage diets for a longer period could be attributed to the insufficient level of available energy and nitrogen content of roughage (Hungate, 1966; Pigden and Bender, 1972; El-Shazly and Naga, 1981; Nicholson, 1984; Preston and Leng, 1984).

Nitrogen requirement of rumen micro-organisms is related to the total available and rumen fermentable energy concentration in the diet (Chesson and Ørskov, 1984). Hungate (1966) calculated the microbial protein output in the rumen as 7 g of protein for every 100 g of digestible organic matter (DOM) in the diet.

Chemical and physical treatments increase available energy concentration of roughage diets, thus causing an increased N-requirements by micro-organisms (Chesson and Ørskov, 1984). Owen (1981) reported that unless poor-quality roughage is treated with nitrogenous chemical compounds, it will always remain a low-protein feedstuff. Ørskov (1983) noted that nitrogen deficiency of straw will be pronounced when it is up-graded with non-nitrogenous chemicals. Pigden and Bender (1972) and Chesson and Ørskov (1984) further stated that effect of treatment on the nutritive value of roughage to ruminant animals could not be realized until it was supplemented with additional N-sources.

Kishan et al. (1973) reported that alkali treatment of straw did not improve feed intake by animals and it was depressed further as the straw was supplemented with 10% molasses. However, an increased feed intake was obtained when the treated straw was supplemented with 1% urea.

Supplementation of low quality roughage with protein feeds is not treatment, but it is an indespensible complement to treatment. Supplementary feeds will correct and balance the nutrient content of the diet, and thus improve feed utilization and animal performance (Pigden and Bender, 1972; Jackson, 1977a; El-Shazly and Naga, 1981;

Nicholson, 1984; Preston and Leng, 1984). Alkali treated straw was reported to replace silage or hay in a diet when it was supplemented with nitrogenous feeds (Jackson, 1978; Abidin and Kempton, 1981).

Minimum N-requirement of rumen micro-organism, for ruminants on low quality roughage as a sole diet, ranges from 0.6-0.8%. A nitrogen content of 1% was suggested for roughage diets of 50% digestibility while nitrogen supplementation at 1.5% level was recommended for roughages of digestibilities higher than 50% (Kishan et al., 1973; Pigden and Heaney, 1969; cited by Pigden and Bender, 1972; El-Shazly and Naga, 1981; Verma and Jackson, 1984; Nicholson, 1984). Jackson (1977a) suggests crude protein levels of 6% in maintenance rations and 8-10% in diets for good animal growth.

A protein supplement to ruminant animals should consist of 70% rumen undegradable protein (RUP) and 30% rumen degradable proten (RDP) (Preston, 1972; Brumby, 1974; O'Donovan, 1975; Ørskov, 1983). Preston (1972) further states that oil seed cakes of sunflower, cotton seed and soybean were good supplements in a molasses based feeding system. He stated that animals on low-protein tropical feed materials responded to supplements of rumen 'by-pass' protein meals when

non-protein nitrogen (NPN) and mineral contents in the diet were corrected. Protein supplements of animal products were observed to have high potential for rumen 'by-pass' nutrients due to the effect of heat during processing (Preston, 1972). Smith et al. (1983) observed that the effect of soybean, rape seed, or urea supplements were inferior to fish meal supplements.

This seemingly better utilization by ruminants of rumen 'by-pass' protein has generated a lot of interest into methods of protecting protein from excessive degradation in the rumen. Preston and Leng (1984) reported that treatment of protein meals by heat, formaldehyde or oil coating or taking advantage of oesophageal groove closure could ensure high proportion of rumen 'by-pass' protein.

Sharma et al. (1972) studied the effect of formaldehyde treatment on rumen solubility of rape seed meal. They observed rumen solubility of 53% and 5.6% for untreated and treated rape seed meal, respectively.

O'Donovan et al. (1972) compared urea with soybean as a supplement for milking cows under zero-grazing conditions. The total dietary nitrogen in the concentrate for one group of cows consisted of 50% N from urea. Cows

fed the urea containing supplement produced 8% less milk than those on soybean meal supplements.

Smith et al. (1983) reviewed several experiments on performance of animals fed treated barley straw supplemented with nitrogenous feeds of different protein sources. The various sources of nitrogen considered were fish meal, soybean meal, rape seed meal and urea. The barley straws studied were either NH_3-treated, ground and pelleted, chopped and NaOH-treated, NaOH-treated and ground, NH_3-stack treated or long and untreated. A higher response in performance was observed in animals fed on all forms of treated straws supplemented with fish meal. It was also observed that straw treatment with NH_3 or urea had the advantage of reducing amount of protein supplement.

Abidin and Kempton (1981) performed two experiments to investigate firstly, the effect of 0, 60, 120, 180, 240, 300g/kg straw levels of untreated and heat treated protein meal supplementation to a barley straw diet on intake and liveweight gain by lambs and secondly the effect of anhydrous NH_3 treatment of barley straw or the combination of both on these parameters. The basal diet consisted of barley straw supplemented with urea and minerals. The results from the first experiment showed

an improved total and straw DMI and live weight gain (LWG) ranging from 9.9 to 51.1%, from 2.8 to 7.1%; and from 65 to 315% at the lowest and highest levels of supplementation, respectively. From the second experiment they observed that NH_3 treatment improved the total and straw DMI and LWG by 3.9, 4.4 and 16.1%, respectively. They concluded that NH_3 treatment improved digestible DMI from straw and LWG; while total DMI and LWG were increased at each level of protein supplementation. Levels of protein supplementation, however, had no significant effect on intake of treated and/or untreated straw.

3. MATERIALS AND METHODS

3.1 EXPERIMENT ONE:

Objectives: To study the effects of levels of urea with urease enzyme treatment, time and moisture content on chemical composition, *in sacco* and *in vitro* dry matter digestibilities of wheat straw.

3.1.1 Materials

The 1984/85 wheat straw was obtained from Tatton Farm, Egerton University College, Njoro. It was collected from four plots each planted with one variety of wheat seed. The size of plots under each seed variety were:

1.	Kenya Nungu	-	7.7 hectares
2.	Kenya Tembo	-	23.3 hectares
3.	Kenya Fahari	-	23.5 hectares
4.	Kenya Kongoni	-	4.5 hectares

The plots were fertilized with diammonium phosphate (DAP) at the rate of 124 kg/hectare. Crops from all plots were combine harvested and straw was baled and bales from all plots stacked together in the barn at Tatton Farm.

Fertilizer grade urea was purchased from local dealers in Nairobi. Urease active jack bean meal was purchased from

Howse and McGeorge Ltd., Nairobi, prepared by BDH Chemicals Ltd., Pools, England. Plastic bags were purchased locally in Nairobi.

3.1.2 Preparation and Treatment of Wheat Straw with 0, 3 and 6% Levels of Urea With Urease Enzyme

Wheat straw was chopped with power driven Simplex chaff cutter to an average length of 2.5 cm. Dry matter content was determined by drying ground samples of about one gram of straw in an oven at 105^{o}C for 24 hours.

One kilogram DM of straw was weighed into each of 24 plastic bags. Straws in 12 bags were sprayed with 710 ml of distilled water to raise the moisture content to 45% level and straws in the other 12 bags were left at 10% moisture content. Distilled water was used to avoid alteration of the proportion of mineral components of the straw which may arise if tap water was used. The weight of straw with 45% moisture content was 1.82 kg per bag while that with 10% moisture content was 1.11 kg bag.

Treatment rates of urea were 0, 40 and 60g per kg DM of wheat straw at both moisture levels. Thus, 12 solutions at 0, 30 and 60g of urea per kg DM of straw per 1.11 litre of distilled water and another 12 solutions at 0, 30, 60g of urea per kg DM of straw per 1.82 litres of distilled water were prepared. Urease active jack bean meal was added to each urea solution (except in 0g urea level) at the rate of 1:2.8 (urease enzyme:urea). Urea solutions were thoroughly stirred.

Application rate of urea solution to straw was one litre per one kilogram of straw 'as is'. Hence, straw with 10% moisture was treated with 1.11 litres while that at 45% moisture content was treated with 1.82 litres of urea solution per bag. Each bag was then tied tightly with string and stored in a shed for either 14 or 28 days.

The experimental design of chemical composition and IVDMD was a completely randomized block of factorial lay out of 3 x 2 x 2, straw treated at three levels of urea, for two treatment times, two moisture contents and replicated twice (Table 3.2).

3.1.3 *In Sacco* Dry Matter Degradability of Urea with Urease Enzyme Treated Wheat Straw

In sacco DM degradability experiment was conducted to determine the effect of treatment factors on straw in accordance with the methods outlined by Kempton (1980) and Ørskov *et al.* (1980). Six fistulated animals consisting of three small East African goats, two Blackhead Somali sheep and one Maasai sheep were used for the experiment. During the experimental period, all animals were fed a mixture of hay and urea treated straw.

The straw samples were tested in duplicate. Thus, all fistulated sheep were assigned to replication one and all goats to replication two. The incubation time periods were 6, 12, 24, 48 and 72 hours.

Table 3.2: Plan for 0, 3 and 6% Levels of Urea with Urease Enzyme Treatment of Wheat Straw, At 10 and 45% Moisture Content, For 14 and 28 Days

Levels of Urea (%)	Treatment Time (days)	Moisture Content (%)
0	14	10
		45
	28	10
		45
3	14	10
		45
	28	10
		45
6	14	10
		45
	28	10
		45

The experimental design for *in sacco* DM degradabilty was a completely randomized block of factorial layout, 3 x 2 x 2 x 5 three levels of urea treatment of straw, for two treatment times, at two moisture content levels, incubated for five incubation time periods and replicated twice (Table 3.3).

Table 3.3: Plan for *in sacco* Dry Matter Degradability Determination of 0, 3 and 6% Levels of Urea with Urease Enzyme Treated Wheat Straw, at 10 and 45% Moisture Contents, for Treatment Times of 14 and 28 Days

Levels of Urea (%)	Treatment Time (Days)	Moisture Content (%)	Incubation Time Interval (Hours)	
			Sheep	Goats
0	14	10	6,12,24,48,72	6,12,24,48,72
		45	" " " " "	" " " " "
	28	10	" " " " "	" " " " "
		45	" " " " "	" " " " "
3	14	10	" " " " "	" " " " "
		45	" " " " "	" " " " "
	28	10	" " " " "	" " " " "
		45	" " " " "	" " " " "
6	14	10	" " " " "	" " " " "
		45	" " " " "	" " " " "
	28	10	" " " " "	" " " " "
		45	" " " " "	" " " " "

3.2 EXPERIMENT TWO:

Objectives: To study the effects of urea treatment and cotton seed cake (CSC) supplementation to wheat straw on Dry Matter Intake (DMI) and performance by wether sheep.

3.2.1 Materials

Wheat straw used was from the same source as that described in Experiment One. Fertilizer grade urea for treatment was purchased from Kenya Grain Growers Cooperative Union (KGGCU), Nakuru. Plastic silos of 2.4 x 2.4 x 1.8m were purchased locally in Nairobi, made to specification.

3.2.2 Preparation of Wheat Straw for *in vivo* Digestability and Feeding Experiment

At the interval of 5 days, 10-15 bales of wheat straw weighing a total of about 150 kg were taken from the barn of Tatton Farm, Egerton University College, Njoro. The bales were stripped open and the straw was kept loose on plastic sheet spread on a concrete floor. One litre of tap water per one kg of straw 'as is' was measured with measuring cylinder and poured into a plastic

bucket. Urea at the rate of 60g per 1kg of straw 'as is' was weighed and dissolved in one litre of water. The urea solution was then applied to the straw at the rate of 1:1 (urea solution:straw), using garden watering can. The treated straw was then thoroughly mixed with a hay fork and hands and transfered to the plastic silos and pressed hard using hand and feet.

The top of the treated straw in the silo was covered with a plastic sheet with all its free ends pushed in, to fit between the walls of the silo and straw. This was felt necessary to avoid the possible leakage of urea-NH_3. Free ends of the silo were then folded in and pressed in to exclude as much trapped-air as possible from the silo. The top of the silo was then tied tightly at four places with ropes, two ropes running length-wise and another two running width-wise.

Nineteen such silos, one for in vivo and eighteen for feeding experiments, were prepared and kept under ambient temperature for 28 days. The minimum and maximum ambient temperatures are indicated in Table 3.4.

At the end of 28 days of treatment time, straw was removed from the silo and kept on a concrete floor and aerated for one day. It was then, chopped to a length of 6-15cm using a manual grass chopper and stored for

feeding. Untreated straw as a control was chopped and treated with tap water at the rate of one litre of water per kilogram of air dry straw on the same day when treated straw was being chopped and stored for feeding.

Table 3.4: The Minimum, Maximum and Average Daily Ambient Temperature (Celsius)

Month	Minimum	Maximum	Average
December	14.3	23.2	19.3
January	13.7	24.9	19.2
February	13.9	25.9	19.9
March	14.1	24.8	19.4
April	14.0	22.8	18.4

3.2.3 Feeding Pens

The experimental sheep were confined in small ruminant animal barn. The lower half of the four walls were covered with off cuts wood and the rest with wire mesh. The barn was partitioned with off cuts wood into 4 compartments, each with 3 pens. The size of each pen was 2.3 x 2.2 x 1.5m. The floor was cleaned, levelled and covered with saw dust. Feeders and waterers, enough for 3 sheep, were installed in each pen. The pens were numbered from 1 - 12.

3.2.4 Animals

Thirty six Corriedale wether sheep of an average age of 6 months and an average initial body weight of 24.2 kg were used in this feeding experiment. The sheep were obtained from Ngongongeri Farm, Egerton University College. They exhibited no visible physical sickness or deformity. The sheep had been vaccinated with a broad-spectrum anticlostridial vaccine against pulpy kidney and blackleg and defleeced while they were on the farm.

All the sheep were moved to the experimental site 20 days before the start of the experiment to adapt to the housing conditions. They were ear tagged after arrival and treated against internal and external parasite. The sheep were then randomly allocated to the twelve pens in lots of three animals per pen.

The experimental design was a completely randomized block of factorial lay out, 2 x 3 i.e. two types of straws, with three levels of CSC supplement replicated twice. The experimental period lasted for 63 days preceeded by 15 days for adaptation to the treatment diets.

3.2.5 Treatment Diets

Undercorticated cotton seed cake (CSC) at 0, 100g and 200g per sheep per day was given as the protein supplement on both types of straw. Sheep in the two pens were assigned to each treatment diet. Composition of the six emperimental diets are indicated in Table 3.5.

Table 3.5: Composition of Untreated and Urea without Urease Enzyme Treated Wheat Straw Diet Fed to Wether Sheep

Ingredients	GROUPS OF SHEEP					
	1	2	3	4	5	6
Untreated straw	ad lib	ad lib	ad lib	-	-	-
Treated straw	-	-	-	ad lib	ad lib	ad lib
CSC g/sheep/day	0	100	200	0	100	200
Maclik Plus* g/sheep/day	14.25	14.25	14.25	14.25	14.25	14.25

Composition of Maclik plus Ca 15.2%, P 6.5%, Na 11.05%, Cl 17.06%, Mg 0.5%, Cu 0.14%, Co 0.061%, Fe 0.4%, K 0.003%, I 0.01%, Zn 0.3%, Mn 0.2%, S 0.2% (elemental); CaO 21.28%, P_2O_5 14.89%, NaCl 28.11% (compound). Ca/P ratio = 2.3:1.

* Coopers Limited, Kenya.

Treatment diets were randomly assigned to sheep in the 12 pens. The daily rations for animals in each pen were fed twice daily, half in the morning at 8.00 hours and the other half at 14.00 hours. Enough quantity of straw was offered to allow selection. Refusals of diets were collected and weighed each morning before feeding the day's ration. Mineral supplement of Macklik Plus at the rate of 14.25g/sheep/day with the respective amounts of CSC supplement were given during the morning feeding. Water was made available ad libitum to all animals.

Samples from diets and refusals were taken daily for DM, ash, CP and CF analyses. These samples were then bulked and preserved in plastic bags and sub-sampled for laboratory analyses.

3.2.6 Additional Data Collection

At the start of the experiment, each sheep was weighed on two consecutive mornings between 06.30 and 08.00 hours before feeding the day's ration. The average of the two days measurement was recorded as the initial body weight. Over the experimental period, each sheep was weighed weekly in the morning between 06.30 and 08.00 hours, on two consecutive days, before they were offered the day's ration. The average of the two days weighings was recorded as body weight of the week.

3.3 EXPERIMENT THREE:

Objectives: To assess the effect of cotton seed cake supplementation to untreated and urea treated wheat straw on *in vivo* digestibility of the straw and total diets.

3.3.1 Metabolic Crates

Twelve individual metabolic crates were used for the *in vivo* digestibility experiment. There were watering, feeding, feaces and urine collection facilities fitted to each metabolic crate. All metabolic crates were kept indoors. The crates were numbered from 1-12.

3.3.2 Animals

The twenty-four sheep on CSC supplemented diet in the previous feeding experiment were grazed for 15 days and received limited amounts of CSC daily. They were treated against internal and external parasites one day before the start of Experiment Three.

On the first day of the experiment, 12 of the 24 sheep were selected, on the basis of body condition and vigour.

They were randomly assigned to each metabolic crate. The experimental design was a completely randomized block of factorial layout, 2 x 3. Each treatment combination was replicated twice.

3.3.3 Treatment Diets

Two animals were randomly assigned to each treatment diet as shown in Table 3.6. Straw offered to each animal was maintained at the intake of animals on untreated straw. Animals were fed twice daily, half of the ration in the morning at 8.00 hours and the other half in the afternoon at 14.00 hours. Water was available to the animals free choice.

Table 3.6: Composition of Diets Fed to Sheep on in vivo Digestibility Trial

Diet Ingredients	GROUPS OF SHEEP					
	1	2	3	4	5	6
Untreated wheat straw	M	M	M	-	-	-
6% Urea treated wheat straw	-	-	-	M	M	M
Cotton seed cake g/sheep/day	0	50	100	0	50	100
Mclik Plus g/sheep/day	14.25	14.25	14.25	14.25	14.25	14.25

M = Maintenance

3.3.4 Collection of Faeces and Urine

The experiment lasted for a total of 17 days, with a 10 days preliminary period and 7 days collection period. Plastic bags of known weight were used for collection of faeces and urine from each crate. The bags were attached to the faeces and urine outlets of the metabolic crates onto a bowl underneath, for 24 hours. 10ml of 6N HCl was put into the urine bags daily as a preservative.

Faeces and urine collection was done every morning before the daily ration was offered. After each collection the bags were changed. Individual bags with faeces were weighed immediately less the weight of the bag. The daily output of faeces was recorded. A graduated cylinder was used to measure the daily output of urine.

3.3.5 Samples

Daily samples of straws offered and refusals were collected and bulked in their respective sample collection bags from which sub-samples were taken at the end of the collection period for DM, CP, CF and ash analyses.

The daily feaces and urine output were mixed thoroughly and 10% samples were bulked over the collection period. All faeces and urine samples were stored in a refrigerator for analyses of chemical composition.

3.3.6 Analytical Methods

All laboratory scale analyses were conducted in the Nutrition Laboratory, Department of Animal Production, University of Nairobi.

Samples of straw from each of the twenty-four plastic bags in Experiment One, feed offered and feed refusal in Experiment Two and Three and faeces in Experiment Three were taken, dried, milled and prepared for analysis of dry matter, ash, crude fiber, and crude protein. Samples of urine in Experiment Three were also taken for analysis of crude protein content. The proximate components indicated above were analysed for in accordance with the procedure stated in Association of Official Agricultural Chemists (AOAC, 1975).

The cell wall constituents (CWC) of straw samples from Experiment I, feed offered and feed refusals and faeces from Experiment III were determined by procedures as described by Georing and Van Soest (1970). *In vitro* dry matter digestibility of samples of wheat straw from Experiment I was determined by Tilley and Terry (1963) method.

3.3.7 Statistical Analyses

All results from Experiment One, Two and Three were subjected to the analyses of variance (Snedecor and Cochran, 1980) and difference between treatment means were compared using LSD (Least significance Differences).

4. RESULTS

4.1 EXPERIMENT ONE: Effects of Levels of Urea with Urease Enzyme Treatment, Time and Moisture on the Chemical Composition, in sacco and in vitro Dry Matter (DM) Digestibilities of Wheat Straw

4.1.1 General Observations

There was a strong smell of NH_3 on opening the silos containing urea with urease enzyme treated wheat straw. The treated straw was golden brown and there was no mould growth nor seed germination. The untreated straw was dark brown and heavily attacked by mould. Mould growth was heaviest with 45% moisture and germinination of seeds; both wheat and any weed seeds in the straw, was observed.

4.1.2 Effect of Urea with Urease Enzyme Treatment on the Chemical Composition of Wheat Straw

The DM content of urea with urease enzyme treated wheat straw for 14 and 28 days, at 10 and 45% moisture, were 45.6 and 27.5%; and 44.8 and 26.9% respectively. The DM content of 0, 3 and 6% urea treated straw samples were 90.7, 91.3 and 91.8%, respectively (Table 4.7). At 0, 3 and 6% levels

of urea, the CP content of the straw was increased ($P<0.05$) from 6.4 to 7.8 and 8.9%, respectively (Table 4.7). However, the CP increment between 0 and 3% levels of urea was 1.4 percentage units compared to the 1.1 percentage units between 3 and 6% levels of urea. Thus, the rate of CP increment appeared to slow down between 3 and 6% levels of urea.

At 0, 3 and 6% levels of urea, NDF was decreased from 82.1 to 79.3 and 77.7%, respectively (Table 4.7). Reduction in NDF content of the straw between 0 and 3% levels of urea was 2.8 percentage units and this was further reduced by 1.6 percentage units between 3 and 6% levels of urea. Treatment mean values of NDF content of the straw at three levels of urea were significantly ($P<0.05$) different. Hemicellulose, ADF and ADL were significantly ($P<0.05$) reduced between 0 and 6%, but not between 0 and 3% or 3 and 6% levels of urea. The CF, ash and silica content of the straw were not affected ($P>0.05$) by urea treatment (Table 4.7).

Table 4.7: Effect of 0, 3 and 6% Urea with Urease Enzyme Treatment on Chemical Composition of Wheat Straw (DM Basis)

Components	Levels of Urea (%)		
	0	3	6
Proximate Composition %			
Dry matter (DM)	90.7	91.3	91.8
Crude protein (CP)	6.4^{a}	7.8^{b}	8.9^{c}
Crude fibre (CF)	40.9^{a}	41.9^{a}	40.9^{a}
Ash	9.2^{a}	8.9^{a}	8.9^{a}
Cell Wall Constituents (CWC) %			
Neutral detergent fibre (NDF)	82.1^{a}	79.3^{b}	77.7^{c}
Acid detergent fibre (ADF)	57.6^{a}	56.9^{ab}	56.1^{b}
Hemicellulose	24.3^{a}	22.9^{ab}	21.3^{b}
Acid detergent lignin (ADL)	7.8^{a}	7.5^{ab}	7.2^{b}
Silica	4.9^{a}	5.0^{a}	4.9^{a}

abc Means on the same row with different letter superscripts are significantly ($P<0.05$) different.

4.1.3 Effect of Treatment Time on the Chemical Composition of Urea with Urease Enzyme Treated Wheat Straw

There was no significant ($P>0.05$) effect of treatment time on the chemical composition of urea with urease enzyme treated wheat straw (Table 4.8).

4.1.4 Effect of Moisture Content on the Chemical Composition of Urea with Urease Enzyme Treated Wheat Straw

When the moisture content of wheat straw during urea with urease enzyme treatment was raised from 10 to 45%, CP was significantly ($P<0.05$) decreased from 8.4 to 7.0%, NDF, ADF and ADL fractions of the CWC were significantly ($P<0.05$) increased from 78.9 to 80.3%; from 56.2 to 57.2% and from 7.2 to 7.8%, respectively (Table 4.9). The remaining chemical components (CF, cellulose, hemicellulose and silica) of the straw were not significantly ($P>0.05$) affected by moisture levels.

Table 4.8: Effect of Treatment Time of 14 and 28 Days on Chemical Composition of Urea with Urease Enzyme Treated Wheat Straw (DM Basis)

Components	Treatment Time (days)	
	14	28
PROXIMATE COMPOSITIONS (%)		
Crude protein (CP)	7.9	7.6
Crude fibre (CF)	41.0	41.5
CELL WALL CONSTITUENT (CWC) (%)		
Neutral detergent fibre (NDF)	79.7	79.5
Acid detergent fibre (ADF)	56.9	56.8
Hemicellulose	22.9	22.7
Acid detergent lignin (ADL)	7.5	7.5
Silica	5.0	4.9

Table 4.9: Effect of Moisture Content of 10 and 45% on Chemical Composition of Urea with Urease Enzyme Treated Wheat Straw (DM Basis)

Components	Levels of Moisture (%)	
	10	45
PROXIMATE COMPOSITION (%)		
Crude protein (CP)	8.4[a]	7.0[b]
Crude fibre (CF)	40.9[a]	41.6[a]
CELL WALL CONSTITUENTS (CWC) (%)		
Neutral detergent fibre (NDF)	78.9[a]	80.3[b]
Acid detergent fibre (ADF)	56.2[a]	57.2[b]
Hemicellulose	22.7[a]	23.1[a]
Acid detergent lignin (ADL)	7.2[a]	7.8[b]
Silica	4.8[a]	5.1[a]

[ab] Means on the same row with different letter superscripts are significantly ($P<0.05$) different

4.1.5 Effect of Interactions between Treatment Factors (Urea with Urease Enzyme and Time; Urea with Urease Enzyme and Moisture; Time and moisture; Urea with Urease Enzyme and Time and Moisture) on the Chemical Composition of Wheat Straw

When straws with 10 and 45% moisture content were treated at 0, 3 and 6% levels of urea, CP was increased from 6.5 to 8.4 and 10.4%; from 6.4 to 7.2 and 7.4 and NDF was reduced from 81.9 to 79.1 and 75.6%; from 82.4 to 79.5 and 79.1%, respectively (Table 4.10). At the same levels of urea, the ADF content of straw with 10% moisture was reduced from 57.8 to 55.9 and 54.8%; and at 45% moisture content, ADF content was 57.9, 56.9 and 57.3%, respectively (Table 4.10). All treatment means of CP, NDF and ADF contents of the straw with 10% moisture content were significantly ($P<0.05$) different. The treatment means of CP and NDF of straw with 45% moisture content were significantly ($P<0.05$) different between 0 and 3%; and 0 and 6%, but not between 3 and 6% levels of urea.

Table 4.10: Effect of Interactions Between Urea with Urease Enzyme Treatment and Moisture Content on Crude Protein (CP), Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) Contents of Wheat Straw (DM Basis)

Moisture Content (%)	Chemical Composition (%)	Levels of Urea (%) 0	3	6
10	CP	6.5^{a}	8.4^{b}	10.4^{c}
	NDF	81.9^{a}	79.1^{b}	75.6^{c}
	ADF	57.8^{a}	55.9^{b}	54.8^{c}
45	CP	6.4^{a}	7.2^{b}	7.4^{b}
	NDF	82.4^{a}	79.5^{b}	79.1^{b}
	ADF	57.9^{a}	56.9^{a}	57.3^{a}

^{abc} Means on the same row with different letter superscripts are significantly ($P<0.05$) different

4.1.6. Effect of Levels of Urea with Urease Enzyme Treatment, Time and Moisture on the *in vitro* Dry Matter Digestibility (IVDMD) of Wheat Straw

Urea with urease enzyme treatment significantly ($P < 0.05$) increased IVDMD of wheat straw from 41.3 to 44.7%. At 0, 3 and 6% levels of urea, the IVDMD of the straw was increased from 41.3 to 44.1 and 45.2%, respectively (Tables 4.11 and 4.12). *In vitro* dry matter digestibility (IVDMD) of straw was improved by 2.8 percentage units between 0 and 3% and only 1.1 percentage units between 3 and 6% levels of urea. Treatment means of IVDMD of the straw at the three levels of urea were significantly ($P < 0.05$) different.

Extending treatment time of the straw from 14 to 28 days did not affect ($P > 0.05$) IVDMD, viz 43.3 and 43.8%, respectively (Table 4.11). Raising moisture content from 10% to 45% significantly ($P < 0.05$) decreased the IVDMD of the straw from 45.1 to 41.9% (Table 4.12).
There was no significant ($P > 0.05$) interaction effect between the various treatment factors on IVDMD of the straw.

Table 4.11: Effect of 0, 3 and 6% Urea with Urease Enzyme Treatment for 14 and 28 Days on in vitro Dry Matter Digestibility (IVDMD) of Wheat Straw

Treatment Time (days)	Levels of Urea (%)			Average
	0	3	6	
	% IVDMD			
14	40.4[a]	44.5[b]	44.9[b]	43.3
28	42.1[a]	43.8[b]	45.5[c]	43.8
Average	41.3[a]	44.1[b]	45.2[c]	

[abc] Means on the same row with different letter superscript are significantly ($P<0.05$) different.

Table 4.12: Effect of 0, 3 and 6% Urea with Urease Enzyme Treatment at Moisture Content of 10 and 45% on IVDMD of Wheat Straw

Moisture Content (%)	Levels of Urea (%)			Average
	0	3	6	
	% IVDMD			
10	42.1[a]	45.9[b]	47.2[c]	45.1
45	40.4[a]	42.4[b]	43.1[c]	41.9
Average	41.3[a]	44.1[b]	45.2[c]	

[abc] Means on the same row with different letter superscript are significantly ($P<0.05$) different

4.1.7 Effect of Levels of Urea with Urease Enzyme Treatment, Time, Moisture and Incubation Time on *in sacco* Dry Matter (DM) Degradability of Wheat Straw

The *in sacco* DM degradability of 0, 3 and 6% urea treated straw was increased ($P<0.05$) from 27.3 to 32.9 and 39.2%, respectively (Table 4.13). By extending the treatment time from 14 to 28 days, the DM degradability of urea treated straw was improved ($P<0.05$) from 31.9 to 34.4% (Table 4.14). There was no significant ($P> 0.05$) effect of moisture on the DM degradability of straw (Table 4.15). The *in sacco* DM degradability of straw increased from 19.9 to 22.8 to 30.1 to 41.9 and 51.0%, when the incubation time was extended from 6 to 12 to 24 to 48 and 72 hours, respectively. The highest rate of increment in the DM degradability of the straw was recorded between 24 and 48 hours of incubation and the increment was at a lower rate thereafter (Tables 4.13, 4.14 and 4.15). The treatment means of the straw DM degradability were significantly ($P< 0.05$) different between 12 and 24; 24 and 48 and between 48 and 72 hours of incubation but not between 6 and 12 hours of incubation.

4.1.8 Effect of Interactions between Treatment Factors (Incubation Times and Urea with Urease Enzyme Treatment, Time, Moisture and in All Combinations) on the *in sacco* Dry matter (DM) Degradability of Wheat Straw

The *in sacco* DM degradability of 0, 3 and 6% urea treated straw and incubated for 6, 12, 24, 48 and 72 hours were improved from 18.1 to 18.3 and 22.9%; from 20.3 to 22.6 and 25.5%; from 25.8 to 29.3 and 35.1%; from 32.6 to 42.1 and 51.2%; and from 39.5 to 52.2 and 61.4%, respectively (Table 4.13 and Figure 4.1). The effect of interactions of incubation times of 6, 12, 24, 48 and 72 hours, treatment times of 14 and 28 days, moisture content of 10 and 45% and in all combinations on the *in sacco* DM degradability of the straw were statistically insignificant ($P>0.05$) (Tables 4.14 and 4.15 and Figures 4.2 and 4.3).

Table 4.13: Effect of 0, 3 and 6% Urea with Urease Enzyme Treatment and Incubation Times of 6, 12, 24, 48 and 72 Hours on *In Sacco* Dry Matter (DM) Degradability of Wheat Straw

Levels of Urea (%)	Incubation Time (Hours)					
	6	12	24	48	72	
	% DM Degradability					Average
0	18.1[a]	20.3[a]	25.8[b]	32.6[c]	39.5[d]	27.3
3	18.3[a]	22.6[a]	29.3[b]	42.1[c]	52.2[d]	32.9
6	22.9[a]	25.5[a]	35.1[b]	51.2[c]	61.4[d]	39.2
Average	19.8[a]	22.8[a]	30.1[b]	41.9[c]	51.0[d]	

[abcd] Means on the same row with different letter superscript are significantly ($P<0.05$) different

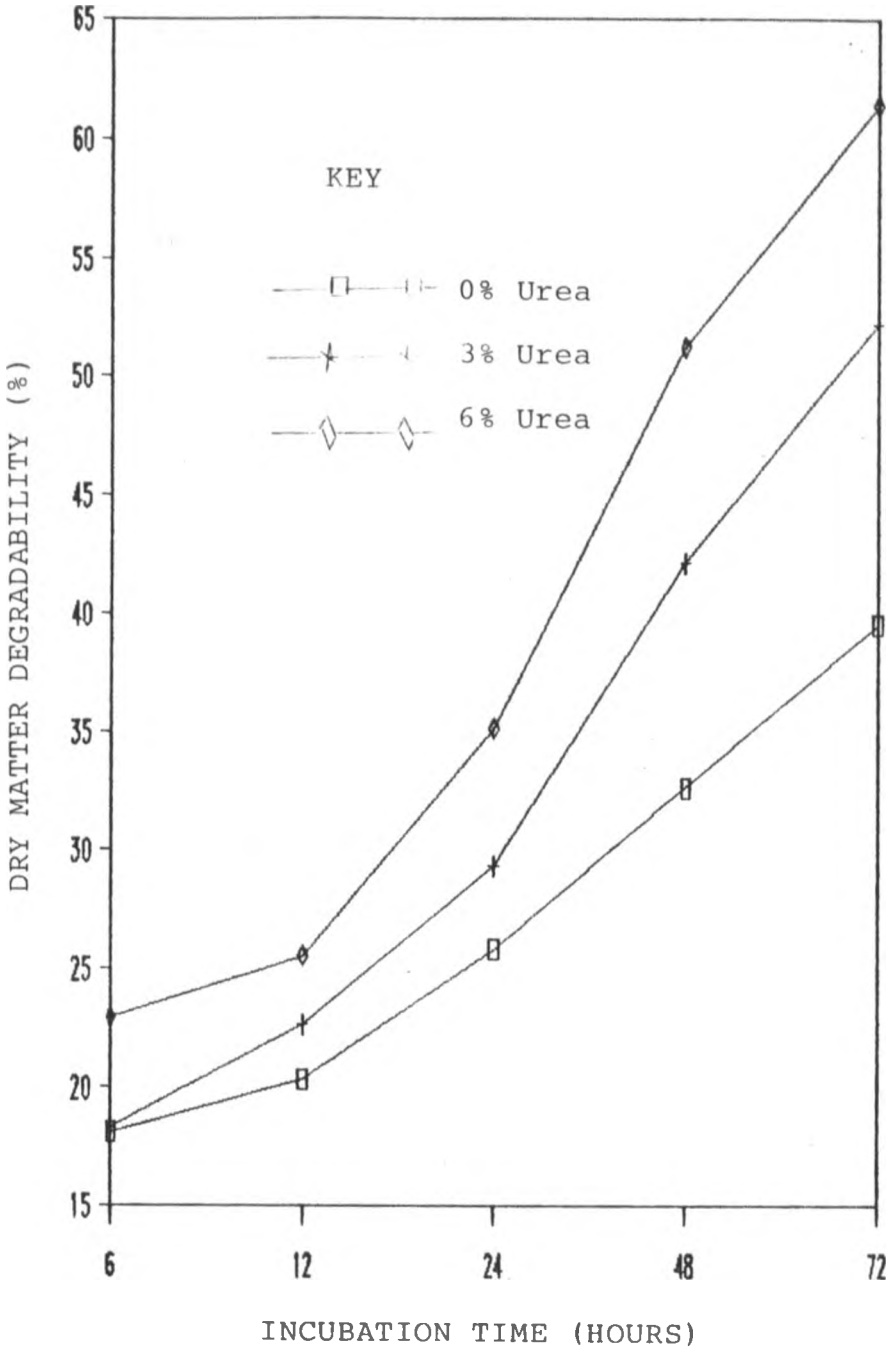

Figure 4.1: The Effect of Urea with Urease Enzyme Treatment and Incubation Time on *In Sacco* DM Degradability of Wheat Straw

Table 4.14: Effect of Treatment Times of 14 and 28 Days and Incubation Time of 6, 12, 24, 48, and 72 Hours on in sacco DM Degradability of Urea with Urease Enzyme Treated Wheat Straw

Treatment Time (Days)	Incubation Time (Hours)					Average
	6	12	24	48	72	
	% DM Degradability					
14	19.7^{a}	22.7^{a}	29.7^{b}	38.4^{c}	49.1^{d}	31.9
28	20.1^{a}	22.9^{a}	30.4^{b}	45.5^{c}	52.9^{d}	34.4
Average	19.9^{a}	22.8^{a}	30.1^{b}	41.9^{c}	51.0^{d}	

^{abcd} Means on the same row with different letter superscript are significantly ($P<0.05$) different.

Table 4.15: Effect of Moisture Content of 10 and 45% and Incubation Time of 6, 12, 24, 48 and 72 Hours on in sacco DM Degradability of Urea with Urease Enzyme Treated Wheat Straw

Moisture Content (%)	Incubation Time (Hours)					Average
	6	12	24	48	72	
	% DM Degradability					
10	20.7^{a}	24.1^{a}	31.9^{b}	42.1^{c}	50.9^{d}	33.9
45	18.9^{a}	21.6^{a}	28.2^{b}	41.9^{c}	50.7^{d}	32.2
Average	19.8^{a}	22.8^{a}	30.1^{b}	41.9^{c}	50.8^{d}	

^{abcd} Means on the same row with different letter superscript are significantly ($P<0.05$) different.

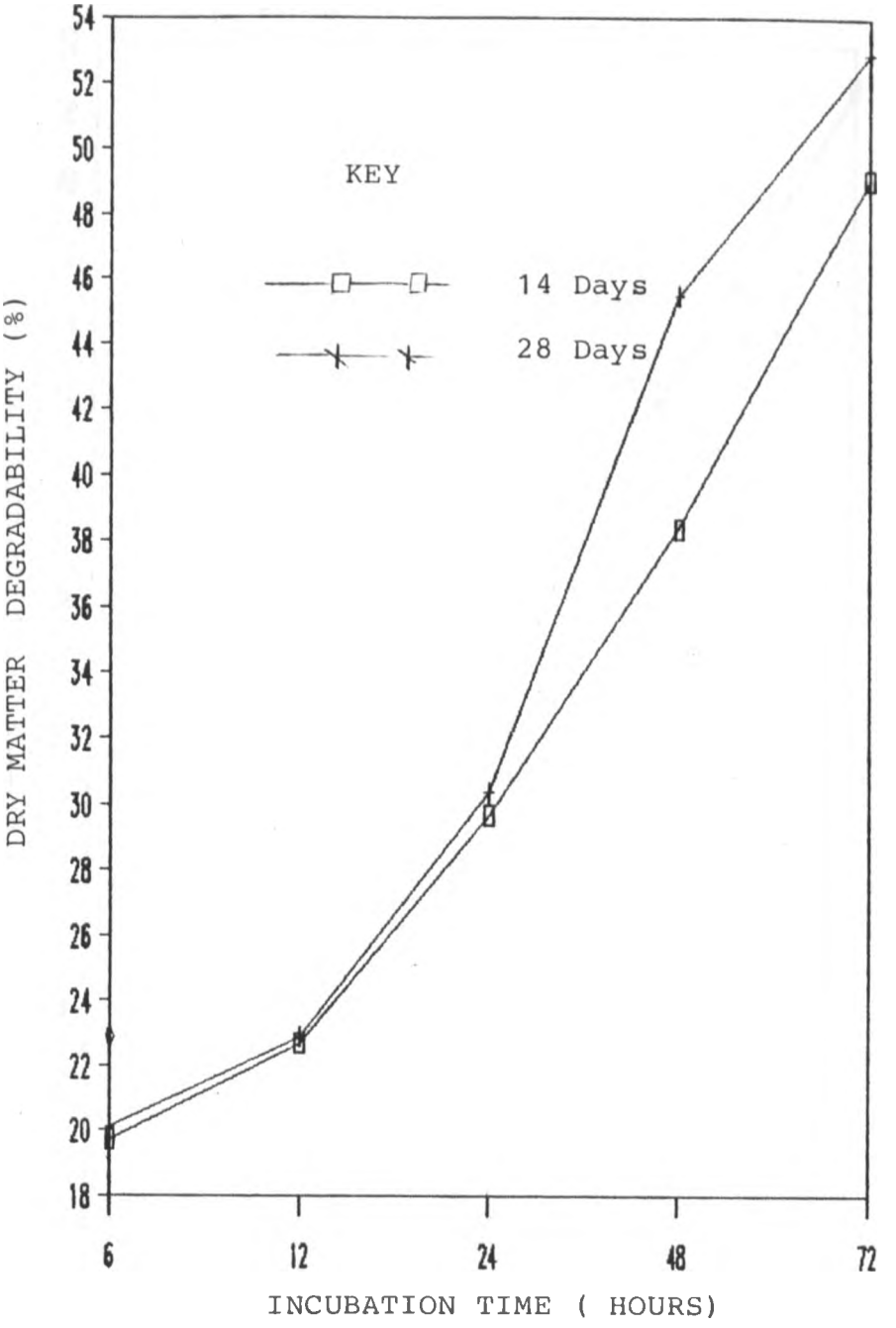

Figure 4.2: The Effect of Treatment Time and Incubation Hours on In Sacco DM Degradability of Urea with Urease Enzyme Treated Wheat Straw

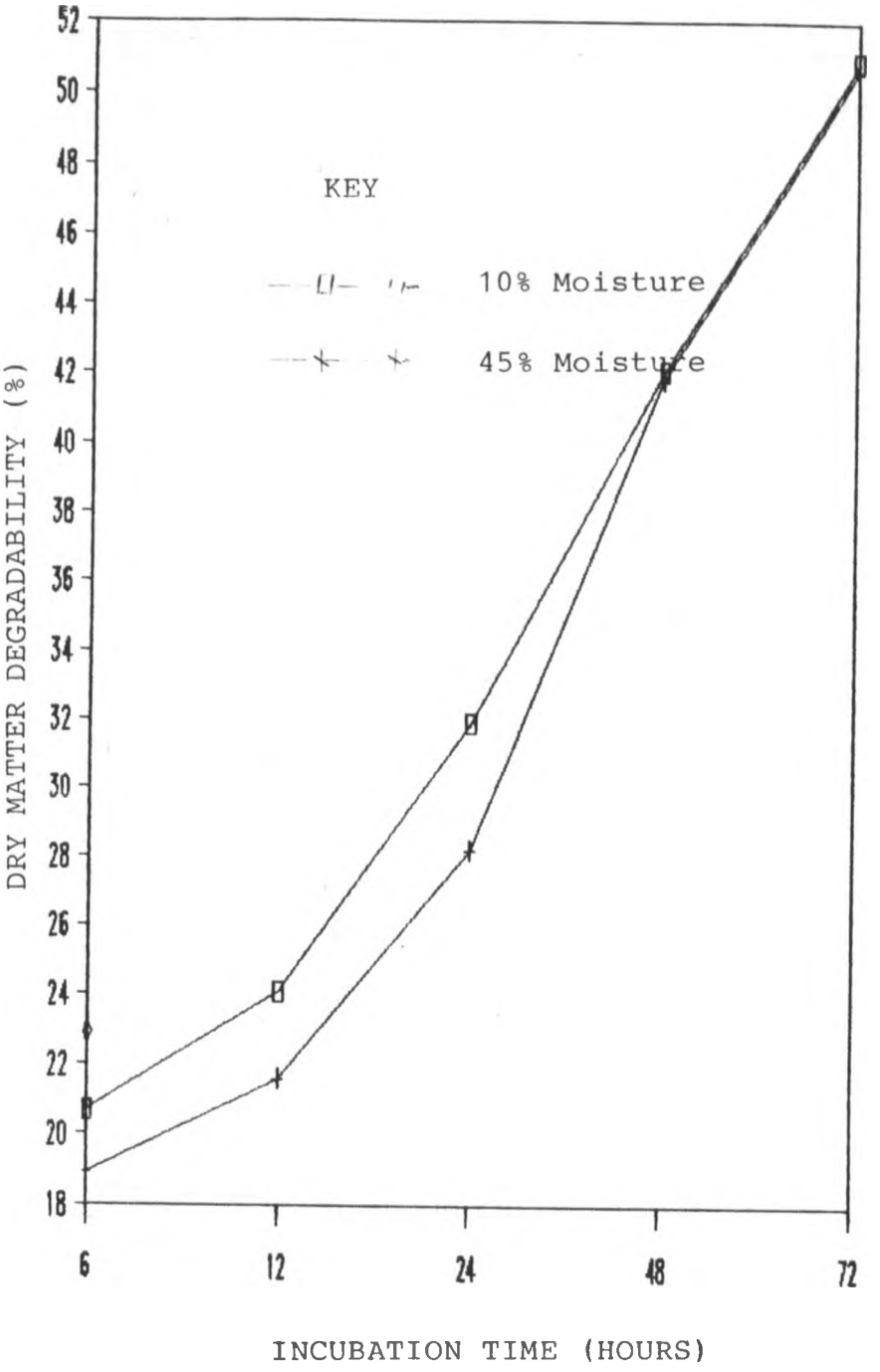

Figure 4.3: The Effect of Moisture Content and Incubation Time on In Sacco DM Degradability of Urea with Urease Enzyme Treated Wheat Straw

4.2 EXPERIMENT TWO: Effect of CSC Supplementation to Urea Without Urease Enzyme Treated Wheat Straw on Dry Matter Intake (DMI) and Live Weight Performance by Wether Sheep

4.2.1 General Observations

When the silos of 6% urea without urease enzyme treated wheat straw were opened the conditions observed were similar to those described in Experiment One. There was a strong smell of NH_3 and the straw was golden brown with no mould growth or seed germination. From the silos of untreated straw there was no smell of NH_3; the straw was dark brown; heavily attacked by mould and almost decaying. There was seed germination. Sheep on the control diet were observed to be unable to feed from such a straw and hence, ensiling of tap water treated wheat straw for 28 days was discontinued.

4.2.2 Effect of Urea Without Urease Enzyme Treatment on the Chemical Composition of Wheat Straw

The DM content of 6% urea without urease enzyme treated wheat straw for 28 days was 46.2%. Chemical compositions of untreated and urea without urease enzyme treated wheat straw samples are indicated in Table 4.16.

Urea treatment significantly (P<0.05) increased the CP and CF content of the straw from 3.5 to 5.1 and from 46.2 to 50.9%, respectively. Hemicellulose and NDF fractions of the CWC were significantly (P<0.05) affected by urea treatment, in which NDF was reduced from 89.3 to 85.9% and hemicellulose from 26.7 to 22.4 (Table 4.16). There was no effect of urea on the remaining components of the CWC (ADF, Cellulose, ADL and Silica) of the straw.

4.2.3 Effect of Urea Without Urease Enzyme Treatment of Wheat Straw on Dry Matter Intake (DMI) by Wether Sheep

The six treatment diets fed to the sheep differed in proximate and cell wall composition (Table 4.17). With a daily supplementation of 100 and 200g of CSC, the CP contents of untreated and urea without urease enzyme treated wheat straw based diets were increased by 2.2 and 4.4; by 2.0 and 4.1 percentage units, respectively. Similarly, the NDF contents of the diets were reduced by 8.6 and 16.2; by 7.1 and 12.9 percentage units, respectively (Table 4.17).

All the 36 experimental sheep were in good health during the feeding periods of 78 days.

Urea treatment significantly (P<0.05) improved the daily straw DMI by the sheep from 462.9g to 597.1g, viz a

Table 4.16: Chemical Composition of 0 and 6% Urea Without Urease Enzyme Treated Wheat Straw for 28 Days (DM Basis)

Components	Type of Straw	
	Untreated	Treated
PROXIMATE COMPOSITION (%)		
Crude protein CP)	3.5[a]	5.1[b]
Crude fibre (CF)	46.2[a]	50.9[b]
CELL WALL CONSTITUENTS (CWC) %		
Neutral detergent fibre (NDF)	89.3[a]	85.9[b]
Acid detergent fibre (ADF)	62.7[a]	63.4[a]
Hemicellulose	26.7[a]	22.4[b]
Cellulose	49.5[a]	50.1[a]
Acid detergent lignin (ADL)	8.5[a]	8.4[a]
Silica	4.7[a]	4.9[a]

[ab] Means on the same row with different letter superscript are significantly ($P<0.05$) different.

Table 4.17: Chemical Composition of 0 and 6% Urea without Urease Enzyme Treated Wheat Straw for 28 Days Based Diets Fed to Wether Sheep at Three Levels of Cotton Seed Cake (CSC) Supplement (DM Basis)

Types of Straw	Untreated			Treated		
Levels of CSC Supplement (g/day/sheep)	0	100	200	0	100	200
Proximate Composition %						
Dry matter (DM)	91.8	91.8	91.8	91.8	91.8	91.8
Organic Matter (OM)	91.3	91.5	90.9	90.5	90.8	91.0
Crude fibre (CF)	50.1	45.3	41.0	54.2	49.7	46.0
Crude protein (CP)	3.9	6.1	8.3	5.5	7.5	9.6
Ash	8.7	8.5	9.0	9.6	9.2	8.9
Cell Wall Constituents (CWC) %						
Neutral detergent fibre (NDF)	89.3	80.7	73.2	85.9	78.7	72.9
Acid detergent fibre (ADF)	62.7	56.7	51.4	63.4	58.2	53.8
Hemicellulose	26.6	24.1	21.8	22.4	20.6	19.0
Acid detergent lignin (ADL)	8.5	7.7	6.9	8.4	7.7	7.1
Silica	4.7	4.2	3.8	4.9	4.5	4.1
Cellulose	49.5	44.7	40.5	50.1	45.9	42.6

28.9% improvement. The DMI by the sheep from untreated and urea treated straw diets, on percent body weight and grammes per unit metabolic body size ($g/kgw^{0.75}$), were 2.0%, 2.4% and 43.1g, 51.1g, respectively (Table 4.18).

4.2.4 Effect of Urea Without Urease Enzyme Treatment of Wheat Straw on the Live Weight Performance of Wether Sheep

Sheep on untreated wheat straw lost live weight at the rate of 15.2g/day and by the end of the experimental period of 63 days they had lost 4.5% of the initial live weight (Table 4.19). Sheep on urea without urease enzyme treated straw, however, recorded ($P<0.05$) a live weight gain of 13.7g/day and by the end of the experimental period of 63 days the gain was 4.6% of their initial weight (Table 4.19).

4.2.5 Effect of Cotton Seed Cake (CSC) Supplementation to Wheat Straw on Dry Matter Intake (DMI) by Wether Sheep

The daily straw DMI by the sheep was not affected ($P>0.05$) by CSC supplementation, viz 518.6 and 536.0g. However, the total daily DMI was increased ($P<0.05$) from 518.6g to 670.7g, viz a 29.3% improvement. At 0, 100 and 200g levels of CSC supplement, the daily straw DMI were 518.6, 554.9 and 517.1g, respectively (Table 4.20). At these

Table 4.18: Dry Matter Intake (DMI) by Wether Sheep on 0 and 6% Urea without Urease Enzyme Treated Wheat Straw for 28 Days

	Types of Straw	
	Untreated	Treated
Straw DMI (g/day)	462.9^{a}	597.1^{b}
Straw DMI (kg/100 kg BW)	2.0^{a}	2.4^{b}
Straw DMI ($g/kg/W^{0.75}$)	43.1^{a}	51.1^{b}

^{ab} Means on the same row with different letter superscript are significantly ($P<0.05$) different.

Table 4.19: Live Weight Change of Wether Sheep Fed on 0 and 6% Urea without Urease Enzyme Treated Wheat Straw for 28 Days.

	Type of Straw	
	Untreated	Treated
Average initial live weight (kg)	24.3	23.9
Average final live weight (kg)	23.2	25.0
Total live weight change (kg)	-1.1^{a}	$+1.0^{b}$
Average Daily live weight change (g)	-15.2^{a}	$+13.7^{b}$
Live weight change (% of initial body weight)	-4.5^{a}	$+4.6^{b}$

^{ab}Means on the same row with different letter superscripts are significantly ($P<0.05$) different

levels of CSC supplement the total daily DMI were improved from 518.6 to 644.3 and 697.0g, viz a 24.3 and 34.4% improvement on control, respectively (Table 4.20). Treatment means of the total daily DMI of the sheep at three levels of CSC supplement were significantly ($P<0.05$) different from each other. When the straw DMI of the sheep were expressed on percent body weight or in gram per unit metabolic body size ($g/kgw^{0.75}$), sheep supplemented with 200g CSC had a lower ($P<0.05$) intake than those on 0 and 100g levels of CSC supplements (Table 4.20). The total DMI of the sheep at 0, 100 and 200g levels of CSC supplement, expressed on percent body weight, was 2.3, 2.7 and 2.7% respectively (Table 4.20).

4.2.6 Effect of CSC Supplementation to Wheat Straw on Live Weight Performance by Wether Sheep

Cotton seed cake (CSC) supplementation to wheat straw improved ($P<0.05$) the live weight performance of the sheep from a loss of 28.9g/day to a gain of 13.4g/day. At 0, 100 and 200g levels of CSC supplement live weight was improved from a loss of 28.9g/day to a loss of 1.7g/day and to a gain of 28.5g/day, respectively (Table 4.21). Treatment means of live weight performance of the sheep at three levels of CSC supplement were significantly ($P<0.05$) different. Live weight changes by the sheep on 100 and 200g levels of CSC supplement was higher by 95.6 and 197.8%, respectively, than those on unsupplemented straw diet. The total live weight changes

Table 4.20: Effect of Cotton Seed Cake (CSC) Supplementation on Straw and Diet DMI by Wether Sheep

	Levels of CSC Supplement (g/sheep/day)		
	0	100	200
Diet DMI (g/Day)	518.6^{a}	644.3^{b}	697.0^{c}
Diet DMI (kg/100 kg (BW)	2.3^{a}	2.7^{b}	2.7^{b}
Diet DMI (g/kg W)$^{0.75}$)	49.3^{a}	56.5^{b}	56.9^{b}
Straw DMI (g/Day)	518.6^{a}	554.9^{a}	517.1^{a}
Straw DMI (kg/100 kg BW)	2.3^{a}	2.3^{a}	1.9^{b}
Straw DMI (g/kg W$^{0.75}$)	49.3^{a}	48.9^{a}	43.9^{b}

^{abc} Means on the same row with different letter superscripts are significantly ($P<0.05$) different.

by the sheep receiving 0, 100 and 200g levels of a daily CSC supplements over the experimental period of 63 days represent -9.0, -0.4 and 8.88% of the initial live weight, respectively (Table 4.21).

4.2.7 Effect of Interaction between Urea without Urease Enzyme Treatment and CSC Supplementation to Wheat Straw on DMI by Wether Sheep

The straw DMI of the sheep from untreated and urea without urease enzyme treated wheat straw diets was not affected ($P>0.05$) by CSC supplement. However, the total DMI of the sheep from untreated and urea treated straw based diets were increased significantly ($P<0.05$) from 457.9 to 582.5 and 620.2g; and from 580.9 to 706.7 and 774.9g respectively, when supplemented with 100 and 200g levels of CSC (Table 4.22). The total DMI of the sheep from 100 and 200g levels of CSC supplemented untreated and urea treated straw based diets was improved ($P<0.05$) by 27.2 and 35.5%; by 21.7 and 33.4%, when compared to sheep on unsupplemented straw diets, respectively (Table 4.22).

Table 4.21: Effect of Cotton Seed Cake (CSC) Supplementation to Wheat Straw on Live Weight Change of Wether Sheep

	Levels of CSC Supplement (g/sheep/day)		
	0	100	200
Number of sheep	12	12	12
Average initial live weight (kg)	24.4	24.3	23.8
Average final live weight (kg)	22.3	24.1	25.9
Total live weight change (kg)	-2.2^{a}	-0.1^{b}	$+2.1^{c}$
Average daily live weight change (g)	-28.9^{a}	-1.7^{b}	$+28.5^{c}$
Live weight change (% of initial body weight)	-9.0^{a}	-0.4^{b}	$+8.8^{c}$

^{abc}Means on the same row with different letter superscripts are significantly ($P<0.05$) different.

Table 4.22: Effect of Urea without Urease Enzyme Treatment and Cotton Seed Cake (CSC) Supplementation to Wheat Straw on Straw and Diet DMI by Wether Sheep

Types of Straw	Level of CSC Supplement (g/sheep/day) 0	100	200
A. UNTREATED			
Total diet DMI(g/day)	457.9^{a}	582.5^{b}	620.2^{b}
Total diet DMI(% B.wt.)	2.1^{a}	2.6^{b}	2.6^{b}
Total diet DMI($g/kgW^{0.75}$)	47.3^{a}	57.9^{b}	57.5^{b}
Straw DMI (g/day)	457.9^{a}	492.5^{a}	440.2^{a}
Straw DMI (% B.wt.)	2.1^{a}	2.2^{a}	1.8^{b}
Straw DMI ($g/kgW^{0.75}$)	47.3^{a}	48.9^{a}	40.8^{b}
B. TREATED			
Total diet DMI(g/day)	580.9^{a}	706.7^{b}	774.9^{c}
Total diet DMI(% B.wt.)	2.5^{a}	2.8^{b}	3.1^{c}
Total diet DMI($g/kgW^{0.75}$)	54.9^{a}	63.0^{b}	68.1^{c}
Straw DMI(g/day)	580.6^{a}	616.7^{a}	594.9^{a}
Straw DMI(% B.wt.)	2.5^{a}	2.5^{a}	2.3^{a}
Straw DMI($g/kgW^{0.75}$)	54.9^{a}	55.0^{a}	52.3^{c}

^{abc} Means on the same row with different letter superscripts are significantly ($P<0.05$) different.

4.2.8 Effect of Interaction between Urea Without Urease Enzyme Treatment and CSC Supplementation to Wheat Straw on Live Weight Performance by Wether Sheep

At 0, 100 and 200g levels of CSC supplement to untreated and treated straw, the live weight performance of the sheep was improved ($P<0.05$) from a loss of 53.4g/day to a loss of 22.2g/day and a gain of 0.9g/day; from a loss of 3.2g/day to a gain of 7.6g/day and 30.5g/day, respectively (Table 4.23). These live weight changes represented losses of 13.5 and 5.9 and a gain of 0.3%; a loss of 0.8 and gains of 1.9 and 8.2%, respectively of the initial live weights of the animals (Table 4.23). Treatment means of live weight changes of the sheep on untreated and urea treated straw based diets supplemented at three levels CSC were significantly ($P<0.05$) different. The protein equivalent of 6% urea without urease enzyme treated wheat straw appears to lie between 100 and 200g levels of CSC supplement.

Table 4.23: Effect of Urea without Urease Enzyme Treatment and Cotton Seed Cake (CSC) Supplementation to Wheat Straw on Live Weight Change of Wether Sheep

Types of Straw	Level of CSC Supplement (g/sheep/day) 0	100	200
A. UNTREATED			
Average initial live weight (kg)	23.0	23.9	24.1
Average final live weight (kg)	21.7	22.5	24.1
Total live weight change (kg)	-3.4	-1.4	+0.1
Average daily live weight change (g)	-53.4^{a}	-22.2^{b}	$+0.9^{c}$
Live weight change (% of the initial Lwt.)	-13.5^{a}	-5.9^{b}	$+0.3^{c}$
B. TREATED			
Average initial live weight (kg)	23.9	24.6	23.5
Average final Lwt (kg)	23.7	25.1	25.4
Total live weight change (kg)	-0.2^{a}	$+0.5^{b}$	$+1.9^{c}$
Average daily live weight change (g)	-3.2^{a}	$+7.6^{b}$	$+30.5^{c}$
Live weight change (% of initial live weight)	-0.8^{a}	$+1.9^{b}$	$+8.2^{c}$

^{abc} Means on the same row with different letter superscripts are significantly ($P<0.05$) different.

4.3 EXPERIMENT THREE: Effect of CSC Supplementation to Urea Without Urease Enzyme Treated Wheat Straw on *in vivo* Digestibility

4.3.1 Effect of Urea Without Urease Enzyme Treatment on *in vivo* Digestibility of Wheat Straw

Chemical compositions of the six treatment diets fed to the sheep are shown on Table 4.24. The average DM content of the diets was 91.8%. Crude protein and NDF contents of untreated and urea treated straw based diet at 0, 50 and 100g levels of CSC supplement were 3.9, 4.9 and 6.1%; 5.5, 6.5 and 7.5%; 89.3, 85.0 and 80.7%; 85.9, 82.3 and 78.7%, respectively (Table 4.24).

There was no health problem observed with the treatment animals during the *in vivo* digestibility experiment.

Urea treament significantly ($P<0.05$) improved the *in vivo* DMD, OMD, CPD and CFD of wheat straw from 47.8 to 52.9%; from 50.9 to 57.4%; from negative 3.7 to positive 35.2%; and from 65.4 to 72.9%, respectively (Table 4.25). The *in vivo* NDF, ADF, hemicellulose and cellulose digestibilities of treated straw were also improved ($P<0.05$) from 58.1 to 65.6%; from 52.9 to 59.8%; from 70.1 to 82.1; and from 67.9 to 77.6%, respectively (Table 4.25).

Table 4.24: Chemical Composition of Diets for the *in vivo* Digestibility Experiment with Sheep (DM Basis)

Types of Straws	Untreated			Treated		
Levels of (CSC) Supplement (g/ sheep/day)	0	50	100	0	50	100
Proximate Composition %						
Dry Matter (DM)	91.8	91.8	91.8	91.8	91.8	91.8
Organic Matter (OM)	91.3	91.4	91.5	90.5	90.6	90.8
Crude fibre (CF)	50.1	45.6	41.0	54.2	51.9	49.7
Crude protein (CP)	3.9	4.9	6.1	5.5	6.5	7.5
Ash	8.7	8.6	8.5	9.6	9.4	9.2
Cell Wall Constituents (CWC) %						
Neutral detergent fibre (NDF)	89.3	85.0	80.7	85.9	82.3	78.7
Acid detergent fibre (ADF)	62.7	59.7	56.7	63.4	60.8	58.2
Hemicellulose	26.6	25.3	24.1	22.4	21.5	20.6
Acid detergent lignin (ADL)	8.5	8.1	7.7	8.4	8.1	7.7
Silica	4.7	4.5	4.2	4.9	4.7	4.5
Cellulose	49.5	47.1	44.7	50.1	48.1	45.9

Table 4.25: *In vivo* Digestibilities of Dry Matter, Organic Matter, Crude Protein, Crude Fibre and Cell Wall Constituents of 0 and 6% Urea without Urease Enzyme Treated Wheat Straw for 28 Days

Digestibilities of Components (%)	Types of Straw	
	Untreated	Treated
Dry matter (DM)	47.8[a]	52.9[b]
Organic matter (OM)	50.9[a]	57.4[b]
Crude protein (CP)	-3.7[a]	+35.2[b]
Crude fibre (CF)	65.4[a]	72.9[b]
Neutral detergent fibre (NDF)	58.1[a]	65.6[b]
Acid detergent fibre (ADF)	52.9[a]	59.8[b]
Hemicellulose	70.1[a]	82.1[b]
Cellulose	67.9[a]	77.6[b]

[ab]Means on the same row with different letter superscripts are significantly ($P<0.05$) different.

4.3.2 Effect of CSC Supplement on the *in vivo* Digestibility of Wheat Straw Diets

There was no significant (P>0.05) effect of CSC supplement on *in vivo* DM, OM, CF, NDF, ADF, hemicellulose and cellulose digestibilities of the straw diets. At 0, 50 and 100g levels of CSC supplement, the DM, OM, CF, NDF, ADF, hemicellulose and cellulose digestibilities of the diets were increased from 48.4 to 49.8 and 53.1%; from 52.5 to 52.9 and 56.9% from 68. 1 to 68.8 and 70.7%; from 60.6 to 60.8 and 64.2%; from 54.6 to 55.4 and 59.3%; from 75.2 to 74.9 and 76.9%; from 72.1 to 71.4 and 75.9%, respectively (Table 4.26). Cotton seed cake supplementation to straw diets improved (P<0.05) the CPD from -12.4 to +24.7 and to +45.9%at 0, 50 and 100g levels of CSC, respectively (Table 4.26).

4.3.3 Effect of Interaction between Urea Without Urease Enzyme Treatment and CSC Supplementation to Wheat Straw on *in vivo* Digestibility of the Diet

Cotton seed cake supplementation improved *in vivo* DM, OM, CP, CF, NDF, ADF, hemicellulose and cellulose

Table 4.26: *In vivo* Digestibilities of DM, OM, CP, CF and CWC of Wheat Straw Diets at Three Levels of Cotton Seed Cake (CSC) Supplement

Digestibilities of Components (%)	Levels of Supplement (g/sheep/day)		
	0	50	100
Dry matter (DM)	48.4[a]	49.8[a]	53.1[a]
Organic matter (OM)	52.5[a]	52.9[a]	56.9[a]
Crude protein (CP)	-12.4[a]	+24.7[b]	+45.9[c]
Crude fibre (CF)	68.1[a]	68.8[a]	70.7[a]
Neutral detergent fibre (NDF)	60.6[a]	60.8[a]	64.2[a]
Acid detergent fibre (ADF)	54.6[a]	55.4[a]	59.3[a]
Hemicellulose	75.2[a]	74.9[a]	76.9[a]
Cellulose	72.1[a]	71.4[a]	75.9[a]

[abc] Means on the same row with different letter superscripts are significantly ($P<0.05$) different.

digestibilities of both untreated and treated wheat straw diets although this effect was more pronounced on the untreated straw diets. At 0, 50 and 100g levels of CSC supplements, the *in vivo* DM, OM, CP, CF, NDF, ADF hemicellulose and cellulose digestibilities of untreated straw diets were increased from 44.7 to 47.6 and 51.2%; from 48.0 to 49.5 and 55.2%; from negative 40.9 to positive 13.6 and 38.2%; from 63.4 to 64.9 and 68.1%; from 56.2 to 56.5 and 61.6%; from 50.7 to 51.8 and 56.4%; from 68.8 to 67.4 and 74.2; and from 66.4 to 66.8 and 70.7%, respectively (Table 4.27). At the same levels of CSC supplement, CP was the only component of urea treated straw diet whose digestibility was improved significantly ($P<0.05$) from 16.0 to 35.8 and 53.8, respectively (Table 4.27). Treatment means of DMD of untreated and CPD of both untreated and urea treated straw diets supplemented at the three levels of CSC were all significantly ($P<0.05$) different. Treatment means of digestibilities of the remaining chemical components of the untreated straw diets were significantly ($P<0.05$) different between 0 and 100g; and 50 and 100g levels of CSC; but not ($P>0.05$) between 0 and 50g levels of CSC supplement.

Table 4.27: Effect of Interaction between Urea without Urease Enzyme Treatment and CSC Supplementation on *in vivo* Digestibility of Wheat Straw Based Diet

Digestibilities of Components (%)	Levels of CSC Supplement (g/sheep/day)		
Types of Straw	0	50	100
A. UNTREATED			
Dry Matter (DM)	44.7[a]	47.6[b]	51.2[c]
Organic Matter (OM)	48.0[a]	49.5[a]	55.2[b]
Crude Protein (CP)	-40.9[a]	+13.6[b]	+38.2[c]
Crude Fibre (CF)	63.4[a]	64.9[a]	68.1[b]
Neutral Detergent Fibre (NDF)	56.2[a]	56.5[a]	61.6[b]
Acid Detergent Fibre (ADF)	50.7[a]	51.8[a]	56.4[b]
Hemicellulose	68.8[a]	67.4[a]	74.2[b]
Cellulose	66.4[a]	66.8[a]	70.7[b]
B. TREATED			
Dry Matter (DM)	52.3[a]	51.9[a]	54.9[a]
Organic Matter (OM)	56.9[a]	56.5[a]	58.8[a]
Crude Protein (CP)	16.0[a]	35.8[b]	53.8[c]
Crude Fibre (CF)	72.1[a]	72.6[a]	73.4[a]
Neutral Detergent Fibre (NDF)	64.9[a]	65.0[a]	66.8[a]
Acid Detergent Fibre (ADF)	58.4[a]	58.9[a]	62.1[a]
Hemicellulose	81.6[a]	82.3[a]	79.5[a]
Cellulose	75.9[a]	75.9[a]	78.9[a]

[abc] Means in the same row with different letter superscripts are significantly ($P<0.05$) different.

5. DISCUSSION

5.1 Characteristics of Urea with and/or Without Urease Enzyme Treated Wheat Straw

The strong smell of NH_3 detected from silos of urea treated wheat straw was as a result of liberation of the gas from the decomposing urea; and it is that portion of NH_3 which did not react chemically with wheat straw. Urea decompses according to the following formula:

$$NH_2 - \underset{\underset{\|}{O}}{C} - NH_2 + H_2O \xrightarrow{\text{Urease}} 2NH_3 + CO_2$$

In silos of urea treated straw, there was neither mould growth nor seed germination and the colour of the straw was golden brown. These general physical characteristics of urea treated straw were apparent even when urease enzyme was not added. It would thus appear that the need for adding urease enzyme when wheat straw is being urea treated is doubtful. These observations were in line with reports from several experiments. The effect of destroying the germinating capacity of seed; the simultaneous preserving and upgrading benefits of NH_3

treatment of straws at higher moisture content were reported by Kiangi (1981) Sundstøl (1981a) Arnaldo and Sundstøl (1986). The change in colour of straw, the smell of NH_3 and the preserving potential of urea with rice straw were also reported by Dolberg et al. (1981a) and Saadullah et al. (1981a).

5.2 Effect of Urea with Urease Enzyme Treatment, Time and Moisture on the Chemical Composition of Wheat Straw

Crude protein content of untreated wheat straw ranged from 3.5 to 6.4%. Similar high CP content ranging from 3 to 6% for spring wheat straw was reported by White et al. (1981) cited by Nicholson (1984). The effect of urea on CP content of straw could be attributed to the binding of NH_3-N to the straw chemically, and the increase of CP with levels of urea could also be due to the effect of the added urea. When compared to untreated straw, the CP contents of 3% and 6% urea with urease enzyme and 6% urea without urease enzyme treated straw were higher by 1.4, 2.5 and 1.6 percentage units, respectively. These results indicate that application of enzyme to urea while treating straw even at lower rate of urea could be beneficial to initiate the quick and complete decomposition of urea to NH_3 (Jayasuriya and Pearce, 1983). An increased CP content

for NH_3 and urea-treated straw has been reported by several workers (Abidin and Kempton, 1981; Coxworth et al., 1981; Hossain and Rahman, 1981: Wanapat, et al. 1985). The effect of increasing the CP content of straw with levels of NH_3 urea were also reported by Waagepeterson and Thomsen (1977), Sundstøl et al. (1979), Kiangi (1981) and Saadullah et al. (1981a).

The crude fibre content of wheat straw was not affected either by urea or by levels of urea. This differs from the observations by Hossain and Rahman (1981) and Saadullah et al. (1981a) who reported lower CF content for urea-treated rice straw. The inconsistency between the results might have been caused by species difference (wheat versus rice straw) (Rexen and Knudsen, 1984).

The reduction in NDF and ADF content of urea-treated straw could be due to the dissolution effect of urea-NH_3 on hemicellulose and lignin fraction of CWC. Similar effects of NH_3 gas and urea-NH_3 on CWC of straw were reported by Abidin and Kempton (1981) and Verma (1981). The trend of CWC reduction of treated straw with an increasing level of NH_3 and/or urea could be compared with reports by Rexen and Thomsen (1976) and Verma (1981).

Extending treatment time from 14 to 28 days did not affect the chemical composition of urea with urease enzyme treated straw. This may be due to the effect of urease enzyme, which could trigger off the quick decomposition and effective reaction of urea-NH_3 with straw within the first 14 days of treatment time. This observation agrees very well to reports by Kiangi (1981); Hossain and Rahman (1981) and Verma (1981). On the other hand, the current observation contradicts the report by Sundstøl et al. (1979). The discrepancies between results from this experiment and that of Sundstøl et al. (1979), could be the wide time interval compared in the latter, viz one and four weeks, as it is unlikely for the effect of NH_3 treatment on chemical composition of straw to be realized fully in one week of treatment time.

The CF and CWC of straw were not affected by moisture content of the straw during treatment, and this agrees very well to the findings of Kiangi (1981) and Verma (1981). The increment of CP was lower when moisture content of urea treated straw was raised from 10 to 45%. This result is in contrast to the report by Kiangi (1981) when he observed no change in the CP content with urea treated straw at 20 and 40% moisture levels.

5.3 Effect of Urea with Urease Enzyme Treatment, Time and Moisture on IVDMD of Wheat Straw

The increased IVDMD of urea treated straw could be explained by the improved concentration of digestible nutrients; by the enhanced accessibility of CWC to microbial digestion due to the disrupting effect of urea-NH_3 on the chemical arrangement of CWC and by dissolving out lignin which is believed to hinder the microbial digestion (Theander, 1981). This observation is in line with results reported from several experiments. The improved IVDMD of NH_3-treated straw were reported among others, by Abidin and Kempton (1981); Coxworth et al. (1981)& Van de Meer (1981). An increased IVDMD of urea treated straw were also reported by Dolberg et al. (1981a) & Arnaldo and Sundstøl (1986). The increase of IVDMD of straw treated with an increasing dosage of NH_3 was reported by Waagepeterson and Thomsen (1977) and Sundstøl et al. (1979). The present result also agrees very well with the report by Kiangi (1981) when he observed an increased IVDMD of 1.6 and 3.9% percentage units for 2.5 and 5% NH_3, generated from urea, treated wheat straw, respectively.

Treatment time did not affect IVDMD of urea treated wheat straw. This result is contradictory to the reports by Waagepeterson and Thomsen (1977) and Sundstøl et al. (1979).

The IVDMD increment was lower when moisture content of straw was raised from 10 to 45%. Sundstøl et al. (1979) reported a similar negative effect of higher moisture on IVDMD, when they compared IVDMD of NH_3-treated barley straw at 15 and 30% moisture content. Kiangi (1981) reported no difference in IVDMD between urea treated straw at 20 and 40% moisture content. The negative effect of higher moisture content on IVDMD of straw could perhaps be explained by the possible formation of crystals of ammonium 'carbonates' in the silos as suggested by Mason and Owen (1986).

5.4 Effect of Urea with Urease Enzyme Treatment, Time and Moisture on *in sacco* Dry Matter (DM) Degradability of Wheat Straw.

After 48 hours of incubation, 3 and 6% urea treated straw were degraded more by 12.8 and 16.1 percentage units, respectively, than untreated straw. This is in agreement with Wanapat et al. (1986) who observed higher degradability of urea treated straw after 48 hours of incubation.

In sacco DM degradability of straw was increased, when incubation time was extended from 6 to 72 hours. The highest rate of increase in degradation for both 3 and 6% urea treated straw with urease enzyme occured after 48 hours of incubation. Ørskov et al. (1980) suggested a guideline of incubation time for optimum digestion of poor roughage to range from 48 to 72 hours.

In sacco DM degradability of straw was almost doubled, viz 5.6 and 11.9 percentage units, when level of urea was raised from 3 to 6%, respectively. The increased DM degradability of straw could be attributed to the increased intensity of urea-NH_3 treatment effect from the added urea. In a similar manner, Verma (1981) reported improved DM degradability when rice straw was treated with an increasing level of urea.

The straw treated for 28 days was degraded more ($P<0.05$) by 2.3 percentage units than that treated for 14 days. Similarly, Verma (1981) reported a better response of rice straw treated with urea for 28 days. The effect of extended treatment time on DM degradability of straw could be due to the provision of enough time for urea to decompose to NH_3 and react chemically with straw, as suggested by Oji and Mowat (1979a).

Increasing the moistrue content of the straw during treatment depressed the effectiveness of urea in improving DM degradability of straw. Sundstøl et al. (1979) reported a similar negative effect of higher moisture content on enzyme soluble organic matter (ESOM) of NH_3-treated straw. To this effect, Mason and Owen (1986) after ensiling winter wheat at a DM content of 58-74% observed a formation of ammonium 'carbonate' and they suggested that urea could be ineffective in upgrading moist straw in sealed stacks due to

the possible chemical reaction between NH_3 and carbon dioxide forming crystals of ammonium 'carbonate'.

5.5 Effect of Urea Without Urease Enzyme Treatment And Cotton Seed Cake (CSC) Supplementation on *in vivo* Digestibility of Wheat Straw

The increased *in vivo* digestibility of straw could be associated with the dissolving out of inhibitory factor of digestion, viz lignin; the increased exposure of surface area of CWC to rumen microbial digestion by disrupting the chemical bonds of CWC due to urea treatment (Theander, 1981). This observation agrees with reports from other workers. An improved *in vivo* DM digstibility of NH_3 and/or urea treated maize stover, maize cobs and straws were reported by Rashiq (1980), Hossain and Rahman (1981), Saadullah *et al.* (1981a), Tubei and Said (1981) and Van de Meer (1981).

The *in vivo* DM digestibility of straw based diet was improved by CSC supplementation. The improved *in vivo* DM digestibility of the diet could be explained by better cellulolytic activity of rumen microorganism as a result of the incrased level of rumen NH_3-N from the diet. Saadullah *et al.* (1981a) found an increased *in vivo* digestibility of a diet when supplemented with proten. In the annual report of ILCA (1985/86) it was indicated that noug cake supplement at 100g level improved digestibility of a straw based diets.

The untreated straw diet responded better to CSC supplement than that of urea treated wheat straw diet. This suggests that urea treament had mostly supplied the level of rumen NH_3 needed to enhance the normal fermentation activities of rumen microorganisms on the straw. The extent of digestion of diets in the rumen largely depends uponadequate nitrogen being available for the rumen microorganisms (Nicholson, 1984). Pigden and Bender (1972) proposed that 1% nitrogen in the diet appears adequate for cellulose digestion in the rumen for feeds of upto 50% digestibility. Smith et al. (1980) concluded that little change in digestibility of fiber rich diets in young cattle can be expected when CP concentrations are above 8.5% (DM).

5.6 Effect of Urea without Urease Enzyme Treatment of Wheat Straw on DMI and Live Weight Performance by Wether Sheep

Urea treatment improved the daily straw DMI of the sheep by 28.9%. The improved daily straw DMI of the sheep could be explained by the increased level of N and by the improved potential of digestion. This result agrees very well with reports by several workers (Sundstøl et al., 1978; Saadullah et al., 1980; Abidin and Kempton, 1981; Hossain and Rahman, 1981; Nurazzamal and Davis, 1981; Saadullah et al., 1981a; 1981b; Wanapat, 1983; Verma and Jackson, 1984;

Wanapat et al., 1985). Hossain and Rahman (1981) in a feeding experiment fed bulls on urea treated rice straw and observed a daily straw DMI increase of 19.2%. Saadullah et al. (1981a) from a feeding experiment fed bulls on urea treated rice straw and observed a daily straw DMI increase of 19.2%. Saadullah et al. (1981a) from a feeding trial with sheep on urea treated rice straw found an increased daily straw DMI of 28%.

The improved weight gain by the sheep on urea treated straw was due to the increased diet DMI as well as an increased available nutrients concentration in the dry matter consumed. Abidin and Kempton (1981) reported a 16.1% increase of live weight when growing lambs were fed on a basal diet of NH_3-treated straw. Nurazzamal and Davis (1981), Saadullah et al. (1981a) and Wanapat et al. (1985) reported, independently, that animals on untreated straw lost live weight, and maintained or gained weight when fed urea treated straw.

5.7 Effect of CSC Supplementation to Wheat Straw on DMI and Live Weight Performance by Wether Sheep

The daily straw DMI of the sheep was not effected by CSC supplementation; but the total daily DMI of the sheep was improved by CSC supplement. This observation agrees with

the work of Abidin and Kempton (1981) when they reported that straw DMI by animals was not affected by proten supplement.

Annual Report of ILCA (1985/86) indicated that straw DMI by sheep from a diet of teff (Eragrostis teff) straws and molasses/urea was depressed when supplemented with 100g of noug cake (Guizotia abyssinica).

The live weight of sheep was improved by 94.0 and 198.6% when straw diet was supplemented with 100 and 200g of CSC, respectively. The improved weight gain observed may be explained by the increased supply of amino acids and glucogenic compounds from the CSC supplement, the improved digestibility and total DMI. This can also be explained by the ovservations of Ørskov (1983) and Nicholson (1984). Ørskov (1983) suggested that when animals were fed on maintenance ration, the microbial protein produced in the rumen would not be sufficient to meet the nutrient requirments of the animal for body tissue maintenance. Nicholson (1984) reproted that animals fed on low nitrogen and high fibre diets gained weight rapidly when supplemented with protein, particularly with fish meal. Verma and Jackson (1984) observed an increased weight gain by calves on rice straw diets supplemented with 150g of fish meal or 325g of CSC.

5.8 Effect of Interaction between CSC Supplementation and Urea without Urease Enzyme Treatment of Wheat Straw on DMI and Live Weight Performance by Wether Sheep

When sheep on untreated straw diet were supplemented daily with 0, 100 and 200g of CSC, live weight loss was reduced from 13.5%, to 5.9% and 2.5% of the initial live weight, respectively. The improved live weight performance of the sheep on untreated and supplemented straw, could be due to the improvement of N content, digstibility and DMI from the diet. Saadullah et al. (1981a) reported that animals kept on untreated straw lost weight; but gained when they were supplemented with 225g linseed cake.

Sheep on urea treated straw diet supplemented daily with 0, 100 and 200g levels of CSC lost 0.8%, and gained by 1.9%, and 8.2% of their initial live weight, respectively. The improved live weight change of the sheep could be attributed to the increased concentration of digestible nutrients in the diet, improved digestibility and intake from the diet. Urea treatment of straw could help in maintaining rumen-NH_3 level, thus creating an environment conducive for increased microbial protein synthesis in the rumen (Preston and Leng, 1984). Cotton seed cake supplements, could also increase the products of digestion, such as glucogenic compounds and amino acids which are essential

for the synthetic purposes of body tissue. For better production performance, animals must be supplemented with 1/3 of non-protein nitrogen (NPN) and 2/3 of true protein nitrogen (TPN) (Brumby, 1974). Crossbred cows fed on urea-treated teff straw supplemented with 1.2 kg noug cake produced 14% more milk; and milk production was increased by 23% when they were fed on urea treated teff straw supplemented with both noug cake and 1 kg of molasses/10% urea (ILCA Annual Report, 1985/86).

CONCLUSION

Based on the results from these experiments, it is concluded that urea without and/or with urease enzyme treatment of wheat straw effectively reduced ($P < 0.05$) CWC and increased ($P < 0.05$) CP content, IVDMD and *in sacco* DM degradability. Chemical composition and digestibility of wheat straw were improved correspondingly with the increased levels of urea with urease enzyme treatment. However, the magnitude of improvement was slower between 3 and 6% levels of urea, thus indicating that the optimum levels of urea for treatment lies between 3 and 6%.

There were no additional improvements in the nutritive value of wheat straw, when the treatment time was extended from 14 to 28 days. Increasing the moisture content of the straw during treatment to 45% had a negative effect on the nutritive value of the straw. Nevertheless, urea treatment was effective in preserving straws of higher moisture content and in killing the germinating capacity of seeds. Therefore, it was proved that urea treatment is effective in preserving stores of moist straws, provided that NH_3 gas leakage from the silos is restricted by proper sealing.

Urea without urease enzyme treatment, cotton seed cake supplementation and in combination improved ($P<0.05$) the nutritive value of wheat straw to whether sheep. Therefore, maintenance of live weight or low levels of animal performance, during long dry season, could be possible by feeding urea treated straw and supplementation with small quantities of true protein nitrogen could promote further an improved animal performance.

Application of urease enzyme facilitates the quick and complete decomposition of urea to NH_3 and ultimately it shortens treatment time of straw. Even then, if the commercial urease enzyme at its current high price is used, the total treatment cost would be high and uneconomical. Therefore, the use of urease enzyme is recommendable only in places where the sources of enzyme are cheap and locally available. Under higher ambient temperatures of tropical regions, satisfactory treatment is possible by treating straw with high concentration of urea solution, in this case 6% of urea dissolved in one litre plain water and applied per one kg of straw 'as is', for an extended treatment time of 28 days or more.

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APPENDIX 1: ANOVA TABLE FOR THE CRUDE PROTEIN (CP) CONTENT OF 0, 3 AND 6% UREA WITH UREASE ENZYME TREATED WHEAT STRAW, AT 10 AND 45% MOISTURE CONTENTS, FOR TREATMENT PERIODS OF 14 AND 28 DAYS

Sources of Variation	df	SS	MS	F
Total	23	48.862		
Replication	1	0.721	0.721	4.192 NS
A = Treatment	2	24.562	12.281	71.401^{xx}
B = Time	1	0.577	0.577	3.355 NS
C = Moisture	1	11.759	11.759	68.366^{xx}
AB	2	0.103	0.052	0.302 NS
AC	2	9.097	4.549	26.448^{xx}
BC	1	0.115	0.115	0.669 NS
ABC	2	0.038	0.019	0.111 NS
Error	11	1.890	0.172	

^{xx} Significant at $P<0.01$

NS Non-significant

APPENDIX 2: ANOVA TABLE FOR THE CRUDE FIBRE (CF) CONTENT OF 0, 3 AND 6% UREA WITH UREASE ENZYME TREATED WHEAT STRAW, AT 10 AND 45% MOISTURE CONTENT, FOR TREATMENT PERIODS OF 14 AND 28 DAYS

Source of Variation	df	SS	MS	F
Total	23	63.444		
Replication	1	18.079	18.079	9.411[X]
A = Treatment	2	5.014	2.507	1.305 NS
B = Time	1	1.445	1.445	0.752 NS
C = Moisture	1	3.519	3.519	1.832 NS
AB	2	0.508	0.254	0.132 NS
AC	2	3.567	1.784	0.929 NS
BC	1	8.343	8.343	4.343 NS
ABC	2	1.837	0.919	0.478 NS
Error	11	21.132	1.921	

X Significant at $P<0.05$

NS Non-significant

APPENDIX 3: ANOVA TABLE FOR THE NEUTRAL DETERGENT FIBRE (NDF) CONTENT OF 0, 3 AND 6% UREA WITH UREASE ENZYME TREATED WHEAT STRAW, AT 10 AND 45% MOISTURE CONTENTS, FOR TREATMENT PERIODS OF 14 AND 28 DAYS

Sources of Variation	df	SS	MS	F
Total	23	154.013		
Replication	1	14.711	14.711	17.186^{xx}
A = Treatment	2	92.069	46.035	53.779^{xx}
B = Time	1	0.478	0.478	0.558 NS
C = Moisture	1	13.098	13.098	15.301^{xx}
AB	2	7.206	3.603	4.209^{x}
AC	2	12.799	6.399	7.475^{xx}
BC	1	0.182	0.182	0.213 NS
ABC	2	4.056	2.028	2.369 NS
Error	11	9.414	0.856	

^{x} Significant at P< 0.05

^{xx} Significant at P< 0.01

NS Non-significant

APPENDIX 4: ANOVA TABLE FOR THE ACID DETERGENT FIBER (ADF) CONTENT OF 0, 3 AND 6% UREA WITH UREASE ENZYME TREATED WHEAT STRAW, AT 10 AND 45% MOISTURE CONTENTS, FOR TREATMENT PERIODS OF 14 AND 28 DAYS

Source of Variation	df	SS	MS	F
Total	23	54.168		
Replication	1	8.307	8.307	10.021^{xx}
A = Treatment	2	14.929	7.465	9.005^{xx}
B = Time	1	8.688	8.688	10.480^{xx}
C = Moisture	1	5.463	5.463	6.589^{x}
AB	2	0.739	0.369	0.445 NS
AC	2	5.504	2.752	3.319 NS
BC	1	0.369	0.369	0.445 NS
ABC	2	1.051	0.526	0.634 NS
Error	11	9.118	0.829	

^{x} Significant at P<0.05

^{xx} Significant at P<0.01

NS Non-significant

APPENDIX 5: ANOVA TABLE FOR ACID DETERGENT LIGNIN (ADL) CONTENT OF 0, 3 AND 6% UREA WITH UREASE ENZYME TREATED WHEAT STRAW, AT 10 AND 45% MOISTURE CONTENT, FOR TREATMENT PERIODS OF 14 AND 28 DAYS

Sources of Variation	df	SS	MS	F
Total	23	5.680		
Replication	1	0.184	0.184	1.235 NS
A = Treatment	2	1.557	0.779	5.228^{x}
B = Time	1	0.032	0.032	0.215 NS
C = Moisture	1	1.771	1.771	11.886^{xx}
AB	2	0.097	0.049	0.329 NS
AC	2	0.271	0.136	0.913 NS
BC	1	0.027	0.027	0.181 NS
ABC	2	0.102	0.051	0.342 NS
Error	11	1.639	0.149	

^{x} Significant at P<0.05

^{xx} Significant at P<0.01

NS Non-significant

APPENDIX 6: ANOVA TABLE FOR THE HEMICELLULOSE CONTENT OF 0, 3 AND 6% UREA WITH UREASE ENZYME TREATED WHEAT STRAW, AT 10 AND 45% MOISTURE CONTENTS, FOR TREATMENT PERIODS OF 14 AND 28 DAYS

Sources of Variation	df	SS	MS	F
Total	23	85.286		
Replication	1	0.920	0.920	0.357 NS
A = Treatment	2	34.869	17.435	6.774[x]
B = Time	1	0.400	0.400	0.155 NS
C = Moisture	1	0.443	0.443	0.172 NS
AB	2	11.357	5.679	2.206 NS
AC	2	2.418	1.209	0.469 NS
BC	1	0.035	0.035	0.014 NS
ABC	2	6.528	3.264	1.268 NS
Error	11	28.316	2.574	

x Significant at $P<0.05$

NS Non-significant

APPENDIX 7: ANOVA TABLE FOR THE IN VITRO DRY MATTER DIGESTIBILITY (IVDMD) OF 0, 3 AND 6% UREA WITH UREASE ENZYME TREATED WHEAT STRAW, AT 10 AND 45% MOISTURE CONTENTS, FOR TREATMENT PERIODS OF 14 AND 28 DAYS

Sources of Variation	df	SS	MS	F
Total	23	191.109		
Replication	1	6.731	6.731	1.606 NS
A = Treatment	2	65.034	32.517	7.757^{xx}
B = Time	1	1.607	1.607	0.383 NS
C = Moisture	1	56.396	56.396	13.453^{xx}
AB	2	5.838	2.919	0.696 NS
AC	2	5.819	2.909	0.694 NS
BC	1	1.944	1.944	0.464 NS
ABC	2	1.630	0.815	o.194 NS
Error	11	46.110	4.192	

xx Significant at P<0.01

NS Non-significant

APPENDIX 8: ANOVA TABLE FOR THE INSACCO DRY MATTER (DM) DEGRADABILITY OF 0, 3 AND 6% UREA WITH UREASE ENZYME TREATED WHEAT STRAW AT 10 AND 45% MOISTURE CONTENT, FOR TREATMENT PERIODS OF 14 AND 28 DAYS, AND INCUBATED FOR 6, 12, 24, 48 AND 72 HOURS.

Source of Variation	df	SS	MS	F
TOTAL	119	23004.380		
Replication	1	17.660	17.660	0.764 NS
A = Treatment	2	2860.410	1430.205	61.906^{XX}
B = Time	1	171.840	171.840	7.438^{XX}
C = Moisture	1	79.340	79.340	3.434 NS
D = Hours	4	16597.180	4149.295	179.599^{XX}
AB	2	129.490	64.745	2.802 NS
AC	2	58.270	29.135	1.261 NS
AD	8	1028.110	128.514	5.563^{XX}
BC	1	7.540	7.540	0.326 NS
BD	4	217.380	54.345	2.352 NS
CD	4	61.910	15.478	0.669 NS
ABC	2	50.470	25.235	1.092 NS
ABD	8	63.940	7.993	0.346 NS
ACD	8	136.720	17.090	0.739 NS
BCD	4	75.450	18.863	0.816 NS
ABCD	8	85.590	10.699	0.463 NS
Error	59	1363.080	23.103	

^{XX}Significant at $P < 0.01$

NS Non-significant

APPENDIX 9: ANOVA TABLE FOR THE CP CONTENT OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS

Sources of Variation	df	SS	MS	F
Total	3	2.540		
Treatment	1	2.530	2.530	506.000^{xx}
Error	2	0.010	.005	

^{xx} Significant at P< 0.01

APPENDIX 10: ANOVA TABLE FOR THE CF CONTENT OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS.

Sourse of Variation	df	SS	MS	F
Total	3	23.730		
Treatment	1	22.270	22.270	30.507^{x}
Error	2	1.460	0.730	

^{x}Significant at P < 0.05

APPENDIX 11: ANOVA TABLE FOR THE NDF CONTENT OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS.

Sources of Variation	df	SS	MS	F
Total	3	12.990		
Treatment	1	12.150	12.150	28.929[x]
Error	2	0.840	0.420	

[x]Significant at P< 0.05

APPENDIX 12: ANOVA TABLE FOR THE ADF CONTENT OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS

Sources of Variation	df	SS	MS	F
Total	3	2.060		
Treatment	1	0.480	0.480	0.608 NS
Error	2	1.580	0.790	

NS Non-significant

APPENDIX 13: ANOVA TABLE FOR THE ADL CONTENT OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS.

Sources of variation	df	SS	MS	F
Total	3	1.000		
Treatment	1	0.020	0.020	0.041 NS
Error	2	0.980	0.490	

NS Non-significant.

APPENDIX 14: ANOVA TABLE FOR THE HEMICELLULOSE CONTENT OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS

Sources of Variation	df	SS	MS	F
Total	3	17.610		
Treatment	1	17.470	17.470	249.571^{xx}
Error	2	0.140	0.070	

^{xx}Significant at $P < 0.01$

APPENDIX 15: ANOVA TABLE FOR THE CELLULOSE CONTENT OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS

Sources of Variation	df	SS	MS	F
Total	3	0.630		
Treatment	1	0.390	0.390	3.250 NS
Error	2	0.240	0.120	

NS Non-significant

APPENDIX 16: ANOVA TABLE FOR THE SILICA CONTENT OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS

Sources of Variation	df	SS	MS	F
Total	3	0.210		
Treatment	1	0.050	0.050	0.625 NS
Error	2	0.160	0.080	

NS Non-significant

APPENDIX 17: ANOVA TABLE FOR THE WEEKLY DIET DRY MATTER INTAKE (DMI) BY WETHER SHEEP ON 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS AND SUPPLEMENTED WITH THREE LEVELS OF COTTON SEED CAKE (CSC).

Sources of Variation	df	SS	MS	F
Total	107	64.567		
Replication	1	0.597	0.597	27.136^{xx}
A = Treatment	1	23.679	23.697	1076.318^{xx}
B = Supplement	2	1.539	0.769	34.955^{xx}
C = Week	8	30.929	3.866	175.727^{xx}
AB	2	0.298	0.149	6.773^{xx}
AC	8	2.019	0.252	11.455^{xx}
BC	16	3.138	0.196	8.909^{xx}
ABC	16	1.199	0.075	3.409^{xx}
Error	53	1.169	0.022	

^{xx}Significant at P< 0.01

APPENDIX 18: ANOVA TABLE FOR THE DAILY LIVE WEIGHT CHANGE (g) OF WETHER SHEEP ON 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS AND SUPPLEMENTED WITH THREE LEVELS OF CSC.

Sources of Variation	df	SS	MS	F
Total	11	14846.518		
Replication	1	658.749	658.749	9.261^{x}
A = Treatment	1	3917.937	3917.937	55.088^{xx}
B = Supplement	2	9818.819	4909.409	69.022^{xx}
AB	2	95.374	47.687	0.670 NS
Error	5	355.639	71.128	

^{x} Significant at $P < 0.05$

^{xx} Significant at $P < 0.01$

NS Non-significant

APPENDIX 19: ANOVA TABLE FOR THE INVIVO DMD OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS AND SUPPLEMENTED WITH THREE LEVELS OF CSC

Source of Variation	df	SS	MS	F
Total	11	194.409		
Replication	1	3.318	3.318	0.294 NS
A = Treatment	1	80.135	80.135	7.099[X]
B = Supplement	2	45.465	22.733	2.014 NS
AB	2	9.047	4.524	0.401 NS
Error	5	56.444	11.289	

[X]Signgificant at P <0.05

NS Non-significant

APPENDIX 20: ANOVA TABLE FOR THE INVIVO OMD OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS AND SUPPLEMENTED WITH THREE LEVELS OF CSC

Sources of Variation	df	SS	MS	F
Total	11	235.285		
Replication	1	3.193	3.193	0.369 NS
A = Treatment	1	126.815	126.815	14.681[X]
B = Supplement	2	47.482	23.741	2.748 NS
AB	2	14.606	7.303	0.845 NS
Error	5	43.189	8.638	

[X] Significant at $P < 0.05$

NS Non-significant

APPENDIX 21: ANOVA TABLE FOR THE INVIVO CPD OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS AND SUPPLEMENTED WITH THREE LEVELS OF CSC.

Source of Variation	df	SS	MS	F
Total	11	11429.209		
Replication	1	67.024	67.024	0.858 NS
A = Treatment	1	2984.946	2984.946	38.222^{xx}
B = Supplement	2	6997.101	3498.551	44.799^{xx}
AB	2	989.664	494.832	6.336^{x}
Error	5	390.474	78.095	

^{x} Significant at $P < 0.05$

^{xx} Significant at $P < 0.01$

NS Non-significant

APPENDIX 22: ANOVA TABLE FOR THE INVIVO CFD OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS AND SUPPLEMENTED WITH THREE LEVELS OF CSC.

Sources of Variation	df	SS	MS	F
Total	11	279.242		
Replication	1	7.873	7.873	0.493 NS
A = Treatment	1	167.851	167.851	10.501^{X}
B = Supplement	2	14.859	7.429	0.465 NS
AB	2	8.739	4.369	0.273 NS
Error	5	79.920	15.984	

^{X} Significant at $P < 0.05$

NS Non-significant

APPENDIX 23: ANOVA TABLE FOR THE INVIVO NDFD OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS AND SUPPLEMENTED WITH THREE LEVELS OF CSC.

Sources of Variation	df	SS	MS	F
Total	11	271.796		
Replication	1	3.553	3.553	0.307 NS
A = Treatment	1	168.525	168.525	14.579[x]
B = Supplement	2	33.566	16.783	1.452 NS
AB	2	8.354	4.177	0.361 NS
Error	5	57.798	11.559	

[x] Significant at P< 0.05

NS Non-Significant

APPENDIX 24: ANOVA TABLE FOR THE INVIVO ADFD OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS AND SUPPLEMENTED WITH THREE LEVELS OF CSC.

Sourdes of Variation	df	SS	MS	F
Total	11	266.771		
Replication	1	12.649	12.649	1.039 NS
A = Treatment	1	140.905	140.905	11.581[x]
B = Supplement	2	50.165	25.083	2.062 NS
AB	2	2.216	1.108	0.091 NS
Error	5	60.836	12.167	

[x] Significant at $P < 0.05$

NS Non-significant

APPENDIX 25: ANOVA TABLE FOR THE INVIVO HEMICELLULOSE DIGESTIBILITY OF O AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS SUPPLEMENTED WITH THREE LEVELS OF CSC.

Sources of Variation	df	SS	MS	F
Total	11	527.652		
Replication	1	0.969	0.969	0.047 NS
A = Treatment	1	363.330	363.330	17.661^{xx}
B = Supplement	2	9.462	4.731	0.229 NS
AB	2	51.025	25.513	1.240 NS
Error	5	102.866	20.573	

^{xx} Significant at P <0.01

NS Non-significant

APPENDIX 26: ANOVA TABLE FOR THE INVIVO CELLULOSE DIGESTIBILITY OF 0 AND 6% UREA WITHOUT UREASE ENZYME TREATED WHEAT STRAW FOR 28 DAYS AND SUPPLEMENTED WITH THREE LEVELS OF CSC.

Sources of Variation	df	SS	MS	F
Total	11	358.244		
Replication	1	0.258	0.258	0.056 NS
A = Treatment	1	281.107	281.107	61.404^{xx}
B = Supplement	2	53.475	26.738	5.841 NS
AB	2	0.512	0.256	0.056 NS
Error	5	22.892	4.578	

^{xx} Significant at $p < 0.01$

NS Non-significant.