NUTRITIONAL EVALUATION OF UREA TREATED CENCHRUS CILIARIS GRASS HAY SUPPLEMENTED WITH PALM KERNEL CAKE IN NELLORE SHEEP

By

YERRADODDI RAMANA REDDY
B.V.Sc. & A.H.,

THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
MASTER OF VETERINARY SCIENCE
IN THE FACULTY OF VETERINARY SCIENCE

DEPARTMENT OF ANIMAL NUTRITION
COLLEGE OF VETERINARY SCIENCE, TIRUPATI
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
RAJENDRANAGAR, HYDERABAD - 500 030

NOVEMBER, 1994

CERTIFICATE

Mr YERRADODDI RAMANA REDDY has satisfactorily prosecuted the course of research and that the thesis entitled "NUTRITIONAL EVALUATION OF UREA TREATED CENCHRUS CILIARIS GRASS HAY SUPPLEMENTED WITH PALM KERNEL CAKE IN NELLORE SHEEP" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

DATE: 21-11-1994

(N. KRISHNA)
MAJOR ADVISOR

C E R T I F I C A T E

This is to certify that the thesis entitled "NUTRITIONAL EVALUATION OF UREA TREATED CENCHRUS CILIARIS GRASS HAY SUPPLEMENTED WITH PALM KERNEL CAKE IN NELLORE SHEEP" submitted in partial fulfilment of the requirements for the degree of 'MASTER OF VETERINARY SCIENCE' of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Mr YERRADODDI RAMANA REDDY under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

CHAIRMAN OF THE ADVISORY
COMMITTEE

Thesis approved by the Student Advisory Committee

CHAIRMAN : (N. KRISHNA)
PROFESSOR AND HEAD
DEPARTMENT OF ANIMAL NUTRITION
COLLEGE OF VETERINARY SCIENCE
TIRUPATI

MEMBER : (J. RAMA PRASAD)
ASSOCIATE PROFESSOR
DEPARTMENT OF ANIMAL NUTRITION
COLLEGE OF VETERINARY SCIENCE
TIRUPATI

MEMBER : (R. RAMACHANDRA REDDY)
ASSOCIATE PROFESSOR & HEAD
DEPARTMENT OF FEED & FODDER TECHNOLOGY
COLLEGE OF VETERINARY SCIENCE
TIRUPATI

TABLE OF CONTENTS

NUMBER	C O N T E N T S	PAGE NO.

NUMBER	C O N T E N T S	PAGE NO.

NUMBER	C O N T E N T S	PAGE NO.

LIST OF ILLUSTRATIONS

LIST OF TABLES

ACKNOWLEDGEMENTS

I deem it a privilege to have worked under the esteemed guidance of my major advisor Dr N. Krishna, Ph.D., Professor and Head, Department of Animal Nutrition, College of Veterinary Science, Tirupati. His keen interest, patient hearing, able guidance, conducive nature and constructive criticism have tesselated in me the spirit of confidence to successfully complete this task for which I am grateful to him.

I am extremely grateful to Dr J. Rama Prasad, Ph.D., Associate Professor, Department of Animal Nutrition and Dr R. Ramachandra Reddy, Ph.D., Associate Professor & Head, Department of Feed & Fodder Technology, members of my advisory committee for their valuable guidance and encouragement at every stage of my work.

I sincerely thank Dr Z. Prabhakara Rao, Ph.D., Associate Professor and Dr A. Garudoji, Associate Professor, Department of Animal Nutrition for their valuable suggestions to complete my research work.

I am thankful to Dr D. Venka Reddy, Ph.D., Assistant Professor and Dr D. Srinivasa Rao, Ph.D., Assistant Professor, Department of Feed and Fodder Technology for their help and support during my research work.

Gratitude is expressed to Prof. O. Ramakrishna, Ph.D., Principal, College of Veterinary Science, Tirupati, for providing necessary facilities to carry out the research work successfully.

My sincere thanks are due to all my colleagues, other senior and junior friends. My heartfelt thanks are due to my beloved friends Jagan, Suresh, Raj, Hemachandra, Prabhu, Sekhar, Sharmila, Rama Devi and Aasam Prasanthi.

My heartfelt gratitude is due to my parents, brothers, sisters, Brother-in-law, Sister-in-laws and well wishers for their continuous encouragement and moral support extended during my Master's Programme.

Finally I thank all the non-teaching and other Laboratory staff for their continuous cooperation.

I gratefully acknowledge the Government of Andhra Pradesh for the financial assistance provided in the form of stipend during my M.V.Sc. Programme.

Y. Ramana Reddy

(Y. RAMANA REDDY)

Name of the author	..	YERRADODDI RAMANA REDDY
Title of the thesis	..	NUTRITIONAL EVALUATION OF UREA TREATED CENCHRUS CILIARIS GRASS HAY SUPPLEMENTED WITH PALM KERNEL CAKE IN NELLORE SHEEP
Degree to which it is submitted	..	MASTER OF VETERINARY SCIENCE
Faculty	..	FACULTY OF VETERINARY SCIENCE
Department	..	DEPARTMENT OF ANIMAL NUTRITION
Major Advisor	..	Dr N. KRISHNA Ph.D., PROFESSOR AND HEAD DEPARTMENT OF ANIMAL NUTRITION COLLEGE OF VETERINARY SCIENCE TIRUPATI - 517 502
University	..	ANDHRA PRADESH AGRICULTURAL UNIVERSITY, HYDERABAD - 30.
Year of submission	..	NOVEMBER, 1994

ABSTRACT

Cenchrus ciliaris, popularly known as Anjan grass is a vigorously growing perennial grass, available in plenty in arid and semi-arid areas for feeding sheep under extensive system. Ammoniation through urea treatment was attempted in the present study to improve the nutritive value of Cenchrus hay.

Cenchrus grass hay on DM basis contained 3.89% CP, 70.98% NDF, 39.45% ADF, 31.53% hemicellulose, 28.91% cellulose, 8.11% lignin and 2.43% silica. Effect of 4% urea treatment on Cenchrus hay was studied at 3 moisture levels

of 30, 40 and 50 per cent and 3 incubation intervals of 10, 15 and 20 days. Ammoniation of hay through urea treatment for 10 days at 40% moisture level increased ($P < 0.01$) the CP from 3.89 to 14.04%. The average IVDMD increased ($P < 0.01$) from 27.68 to 41.98% due to urea treatment of hay for 10 days at 40% moisture level.

Higher ($P < 0.01$) average *in sacco* DM disappearance value of 52.13% was observed for hay subjected to 40% moisture level as compared to 30 or 50% moisture levels. The soluble DM fraction 'a', insoluble but degradable DM fraction 'b' were higher for hay moisturised to 40%. Higher effective degradable dry matter (EDDM) values ranging from 39.55 to 40.32% were observed when Cenchrus hay was incubated at 40% moisture for 10 to 20 days.

Results of chemical, *in vitro* and *in sacco* evaluation of 4% urea treated hay have indicated that 40% moisture and 10 days of incubation were found to be optimum conditions for ammoniating Cenchrus hay. Palm kernel cake (PKC), a potential by-product of oil palm industry was used as an energy/protein supplement in the present study. On DM basis the CP, NDF, ADF, hemicellulose, cellulose and lignin levels of PKC were analysed to be 15.05, 74.37, 41.58, 32.79, 22.03 and 17.41 per cent, respectively. During the 4 x 4 latin square designed digestion-cum-metabolism trial, Nellore Brown weaner ram lambs were fed either untreated or urea treated hay with or without 100 g PKC supplementation.

Urea treatment increased ($P < 0.01$) the digestibilities of DM, CP, NDF, ADF, hemicellulose and cellulose from 47.98, 55.13, 51.93, 42.78, 60.31 and 53.52 to 56.92, 66.52, 58.74, 51.08, 67.51 and 61.35 per cent, respectively. Supplementation of urea treated hay with PKC increased the digestibilities of DM ($P > 0.05$) and CP ($P < 0.01$) by 2.98 and 4.26 and that of NDF, ADF, hemicellulose and cellulose ($P > 0.05$) by 1.88, 2.40, 2.58 and 2.87 percentage units, respectively. The DCP and TDN values of Cenchrus hay were 2.14 and 49.16% which increased to 9.35 and 57.71 per cent, respectively due to urea treatment. Supplementation of PKC to treated hay increased ($P < 0.01$) the DCP and TDN values by 0.74 and 5.01 percentage units, respectively. It was further observed that the nitrogen retention was highest in lambs fed treated hay supplemented with PKC.

The results of the present study revealed that Cenchrus ciliaris hay is a potential roughage for ammoniation through urea treatment. Moisture level of 40% with 10 days incubation were found to be optimum treatment conditions for enriching Cenchrus hay through 4% urea treatment. Urea treatment has significantly increased the nutrient digestibility, N utilization and nutritive value of Cenchrus hay. Urea treated hay supplemented with 100 g PKC was found to meet the protein and energy requirements of growing Nellore Brown ram lambs.

ABBREVIATIONS USED

ADF	..	Acid detergent fibre
ADG	..	Average daily gain
ADL	..	Acid detergent lignin
CF	..	Crude fibre
cm	..	Centimeter
CP	..	Crude protein
DCP	..	Digestible crude protein
DE	..	Digestible energy
DM	..	Dry matter
DMB	..	Dry matter basis
DMI	..	Dry matter intake
EDDM	..	Effective degradable dry matter
EDP	..	Effective degradable protein
EE	..	Ether extract
FCM	..	Fat corrected milk
g	..	Gram
h	..	Hour
IVDMD	..	*In vitro* dry matter digestibility
IVNDFD	..	*In vitro* neutral detergent fibre digestibility
IVOMD	..	*In vitro* organic matter digestibility
kg	..	Kilogram
kg $W^{0.75}$	..	Metabolic body size
L	..	Litre
Mcal	..	Megacalorie

ME	..	Metabolizable energy
mm	..	Millimeter
N	..	Nitrogen
NDF	..	Neutral detergent fibre
NFE	..	Nitrogen free extract
NPN	..	Non-protein nitrogen
OM	..	Organic matter
PKC	..	Palm kernel cake
TDN	..	Total digestible nutrients
UDN	..	Rumen undegradable nitrogen
Urea-N	..	Urea nitrogen

CHAPTER - I

1. INTRODUCTION

Crop residues play an important role in meeting the energy and dry matter requirements of livestock in India. Low digestibility associated with poor nitrogen and mineral status have restricted their intake in ruminants adversely affecting their production potential. World-wide interest in utilising low quality roughages and in upgrading their nutritive values for ruminants is increasing. Ammonia treatment has been found to be an effective method of improving the nutritive value of crop residues by the farmers in developing countries. However, the standard method that has been developed and adopted for temperate countries is not found to be feasible under small farm situations in India.

As opposed to gaseous ammonia treatment methods, ammonia released from urea have been suggested as suitable for many developing countries. Recent work of Oji and Mowat (1977) and Williams and Innes (1982) demonstrated that there is extensive breakdown of urea to ammonia when it is added to straw in sealed containers. One of the most promising method of ammoniation is to use fertilizer grade urea as a solution and to preserve the material in air-tight containers for 3-4 weeks. On-farm trials conducted by Agarwal and Verma (1983) divulged that urea-ammonia treated coarse roughage sources offer a great promise for the future of ruminant production in the Indian sub-continent.

Cenchrus ciliaris, popularly known as Anjan grass is a valuable tufted perennial grass available in plenty in arid and semi-arid areas. The grass survives from extreme and prolonged drought conditions besides being nutritious and palatable. Drought resistance and the colonizing ability of this grass to non-planted areas and quick recovery of severely defoliated plants made it most suitable for range improvement and reclamation purposes.

With the introduction of oil palm cultivation in Southern parts of India in the recent past, Palm kernel cake (PKC) will be available in abundance as a by-product of solvent extraction of oil palm. Recent studies of Vasantha Lakshmi and Krishna (1993, 1994) have revealed the potential feeding value of PKC as an energy / protein source for ruminants.

Extensive research work has already been carried out on urea treatment of all the available cereal straws in the country and the standard conditions for their treatment have been well established.

There is a strong need to undertake urea-ammonia treatment of several untapped crop residues and dried grasses. Since no work has been undertaken to improve the nutritive value of Cenchrus grass hay by ammoniation through hydrolysis of urea and its potential feeding value, an attempt has been made in the present study to improve its nutritive value keeping in view the following objectives:

1. To standardise the technique of urea treatment suitable to Cenchrus ciliaris grass hay in terms of optimum moisture level and incubation time.

2. To study the effect of urea treatment on the nutrient digestibility and nutritive value of Cenchrus ciliaris grass hay in sheep and

3. To study the effect of supplementation of palm kernel cake on nutritive value of untreated and urea treated Cenchrus ciliaris grass hay in sheep.

CHAPTER - II

2. REVIEW OF LITERATURE

Anjan (<u>Cenchrus ciliaris</u>) grass covers extensive tracts in India and serves as an excellent roughage source for grazing livestock in the region receiving rainfall ranging from 250 to 1,000 mm (Mandal and Chakravarthy, 1968). In terms of nutritive value the grass ranks very high among the indigenous grasses and relished by all classes of livestock.

2.1 CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF CENCHRUS HAY

2.1.1 Chemical composition

Chemical composition of Cenchrus ciliaris in green and conserved form has been reported by several workers. On DM basis Cenchrus hay had CP 9.74, EE 1.31, CF 40.38, NFE 41.83 and total ash 6.34% (Singh, 1975). As reported by Singh and Mudgal (1988) on DM basis Cenchrus ciliaris (IGFRI-3108) contained 9.28% CP, 2.11% EE, 30.54% CF, 42.13% NFE and 6.93% total ash. Sen <u>et</u> <u>al</u>. (1978) also reported the average values of CP, CF, NFE, EE and total ash of Cenchrus hay as 4.9, 32.9, 51.2, 0.8 and 10.2%, respectively. The protein content of Anjan grass ranged from 3 to 16% according to Narayanan and Dabadghao (1972). As reported by Bhatia et al. (1974) CP content of the grass ranged from 4.3 to 10.3 with below 7% value for more than half time of its growth with CF content ranging from 23.6 to 36.3% with an average of 30.3%.

At 7 weeks of growth the DM (%) and carotene (ppm) contents of Anjan grass were 37.2 and 137.3, respectively (Sen et al., 1978). Chemical composition in terms of detergent system of analysis was reported by Sen et al. (1978). The NDF, ADF, cellulose, hemicellulose, lignin and silica values were 71.95, 37.43, 29.71, 34.52, 6.30 and 1.82%, respectively on DM basis.

The chemical composition of Cenchrus hay representing different stages of growth was reported by Sen et al. (1978). The CP content varied from 5.5 to 16.9% and the lowest values were reported from post-flowering stage onwards. The CF content also increased from 28.5 to 35.3% with the value being lowest for samples representing young stage while the highest values for prime and post flowering stages. Bhatia et al. (1979) reported that the CF content was higher during the drier months of the year. The CP content of Buffel (Cenchrus ciliaris) grass ranged from 5.91 to 9.87% and 3.84 to 7.54% in dry and wet seasons, respectively (Caceres and Garcia, 1982).

Mandal and Chakravarthy (1968) reported the CP content of Cenchrus hay at five different stages of cutting as 10.59, 12.38, 9.75, 9.81 and 8.07%, respectively. The CP content varied from 8.07 to 12.38% and the lowest value was obtained from the 5th cutting while the highest value from the 2nd cutting. Sen (1952) in his earlier bulletin has reported variation in CP and total ash of Anjan grass from 3.00 to 12.42% and 9.14 to 20.85%, respectively, under different habitats in the country. Dabadghao and Gandhi (1952) also reported variation in protein content of Cenchrus ciliaris from 5.30 to 11.88% on DM basis.

2.1.2 Nutritive value of Cenchrus hay

Singh (1975) studied the feeding value of Anjan grass converted into hay at ripe stage. The digestibility coefficients of DM, CP, EE, CF and NFE were 43.85, 53.01, 37.18, 42.78 and 47.67, respectively. The nutritive value in terms of DCP and TDN was determined to be 5.16 and 43.48%, respectively, on DM basis. It was further reported that Anjan grass can be well utilized by sheep as a maintenance fodder. Sen et al. (1978) reported the digestibility coefficients of OM, CP and EE of Cenchrus hay as 57, 35 and 30 with the values for DCP, TDN and nutritive ratio being 1.7%, 51.7% and 1:29.3, respectively.

The performance and feeding value for sheep of IGFRI-3108 variety of Anjan grass was studied by Singh and Mudgal (1988). In their study the rams were allowed to graze 0.75 acres of Cenchrus pasture for 21 days. Digestibility coefficients for DM, CP, EE, CF and NFE were determined to be 48.26, 26.76, 27.62, 45.00 and 58.50, respectively. The average body weight increased by 67 g/head daily. The intake and balance of N was 5.16 and + 0.85 g/head/day, respectively. The DCP and TDN values were worked out to be 2.49 and 48.37%, respectively.

Bhatia et al. (1979) reported the nutritive value of Anjan grass harvested in October, February and August months. The highest DMI (3.60 kg/100 kg body weight/day) was reported for the grass harvested in February when the pasture was comparatively dry. The CF digestibility has been reported to improve during and after the rains. Higher CP digestibility of 70.22% was obtained with Cenchrus grass during February while CF and NFE digestibilities were highest during the monsoon. The N balance remained positive and the DCP and TDN values were highest for the grass harvested during the monsoon.

Caceres and Garcia (1982) compared the nutritive value of Buffel grass grown in dry and wet seasons and reported that the DM intake (g/kg $W^{0.75}$) and milk production values expressed as kg of 4% FCM/day were 53.9-68.1 and 4.6-5.1 in dry season and 44.1-44.9 and 7.6-14.3, respectively in wet season.

The nutritive value of Cenchrus ciliaris representing post maturity stage was determined in Marwari ram lambs by Paul et al. (1979). The intake of ME (Mcal/100 kg $W^{0.75}$) and CP (g/100 kg $W^{0.75}$) were 10.58 and 217.37, respectively with live weight loss of 14 g per day. It was concluded that Cenchrus grass when mature is not sufficient as sole source of nutrient supply to livestock. Since Cenchrus ciliaris could not meet the nutrient requirements of livestock, its nutritive value needs to be improved by supplementation or by employing various processing methods.

2.2 PALM KERNEL CAKE AS AN ENERGY / PROTEIN SOURCE

Oil palm fruit yields a number of by-products of potential importance for livestock feeding. These include the main product palm oil, and three by-products such as palm press fibre (PPF), palm oil mill effluent (POME) and palm kernel cake (PKC). Mustaffa Babjee (1988a) reported that palm kernel cake constitutes 2.0 to 2.2% of palm kernels of fruit bunches. PKC like rice bran has been considered to be a source of both energy and protein by many researchers in Malaysia.

2.2.1 Chemical composition and nutritive value

Incorporation of PKC as an unconventional feed supplement in the rations of livestock is of recent approach in India.

Palm kernel cake was reported to contain 90.6% DM, 19.0% CP, 16.0% CF, 2.0% EE, 4.2% ash and 58.8% NFE with a gross energy value of 17.3 MJ/kg (Devendra, 1977). Recently Vasantha Lakshmi and Krishna (1993) have reported the DM, OM, CP, EE, CF, NFE and total ash content of PKC as 88.18, 91.00, 14.80, 1.28, 33.20, 41.72 and 9.00% and that of NDF, ADF, hemicellulose, cellulose and lignin as 73.56, 38.55, 35.01, 18.39 and 20.50%, respectively. Nutritive value of PKC expressed in terms of DCP and TDN was 7.76 and 52.50%, respectively (Vasantha Lakshmi and Krishna, 1994).

Use of PKC either in the form of expeller processed or solvent extracted oil meal was tried by Ganabathi (1984) in Malaysia. It was concluded that solvent extracted PKC could be used to completely replace conventional mixed concentrate feed for dairy cattle.

Feeding value of PKC based on number of feeding trials was compiled by Yusoff (1985). Four groups of 12 Sahiwal X Friesian heifers were fed diets containing varying levels of PKC with urea solutions of different concentrations at 2 kg/day with napier or guinea grass to appetite. Average daily gain was reported to be 0.64 kg and feed intake 10.56 kg/kg gain.

Sahiwal X Friesian dairy heifers were fed napier grass plus 2 kg of supplementary rations comprising of PKC or in combination with either cassava or molasses as energy supplements (Mustaffa Babjee, 1988a). No significant difference in daily gain among the treatment means was reported, under semi-intensive system of feeding.

Vasantha Lakshmi (1992) studied the effective level of inclusion of PKC in the rations of sheep. She concluded that PKC could be safely incorporated in the complete rations of sheep upto 15% level. In an earlier study, Mustaffa Babjee (1988b) recommended PKC inclusion up to 20% level without any adverse effect on the reproductive performance of goats in Malaysia.

The performance of growing lambs fed grass and PKC at levels of 0, 0.45, 0.90, 1.35 and 1.80% of their live weight was studied by Mustaffa Babjee (1988b) with daily weight gains of 27.5, 51.0, 53.0, 69.0 and 68.0 g/day, respectively with grass and PKC rations. There was significant increase in gain with increased level of PKC supplementation upto 1.35% of their live weight.

2.3 EFFECT OF SUPPLEMENTATION ON ANIMAL PERFORMANCE

Supplementation has been found to be beneficial to forages having less than 7% CP in cattle (Wagner, 1989). Scarcity of good quality roughages and high cost of protein feed necessitates to plan for strategic supplementation. Strategic supplementation of energy, protein and minerals offer an important means to ensure that the animal performance is not affected especially during critical period of shortages.

2.3.1 Supplementation with tree leaves

Supplementation of tree leaves such as Leucaena, Gliricidia and Sesbania to a basal forage of NB-21 grass at 40:60 ratio on DM basis has significantly improved the CP digestibility of whole ration and increased the N retention in native lambs (Veereswara Rao *et al.*, 1992).

Adejumo and Ademoson (1991) observed an ADG of 59.3 and 33.1 g with West African Dwarf sheep and goats supplemented with 40 and 60% of Leucaena tree leaves to Panicum maximum based diets, respectively. They also reported that the digestibility of DM and organic nutrients increased with increased level of Leucaena supplementation.

Mtenga and Shoo (1990) reported that *ad libitum* supplementation of hay with *Leucaena leucocephala* significantly increased the growth rate, total DMI and CP digestibility in goats. The daily N retention was 9.6 g/day as compared to those fed hay which were in negative N balance.

The effect of supplementation with Gliricidia, Albizia, and Sesbania on the intake and digestibility of guinea grass hay by goats was studied by Ash (1990). Supplementation with Gliricidia and Sesbania has significantly increased the total DMI. Albizia supplementation had no effect on total DMI.

The apparent digestibility of DM, OM, CP and NDF was greater in sheep fed on Cenchrus grass supplemented with Leucaena leaves at 20 or 40 g/kg $W^{0.75}$. The DMI increased from 465 to 610 and 659g. Leucaena leucocephala leaves given at 40 g/kg $W^{0.75}$ decreased Buffel (Cenchrus ciliaris) grass intake (Maika et al., 1988).

2.3.2 Supplementation with concentrates

Protein supplements increase glucose availability for intestinal absorption when they are offered as supplementary sources to low quality diets (Lindsay, 1970). Hassan et al. (1991) studied the effect of supplementation of rumen undegradable nitrogen (UDN) on carcass composition of Awassi sheep. Supplementation of high roughage diet with UDN doubled the rate of EE, energy and dissectable gain with little increase in lean gain. Wanyoike et al. (1989) reported that supplementation of cotton seed cake to sheep fed on wheat straw increased the total DMI and changed the live weight gain from -28.9 to 28.5 g/day.

Supplementation of 200 g concentrate daily to goats fed on Chloris gayana hay increased total DMI, decreased feed conversion ratio, increased growth rate and daily CP and energy intake. Supplemented goats had higher dressing % and fat deposit % than in the control goats (Mtenga and Kitlay, 1990). Thomas et al. (1990) reported that supplementation of soyabean meal, blood meal and maize gluten meal, barley grain or soyabean meal plus barley grain to lambs grazing barley stubble significantly increased live weight gain.

Sanchez and Pond (1990) summarized the details of positive response observed in Sumitran Thin tail sheep to supplementary feeding under rubber tree plantations. Ewes under continuous energy supplementation with mixed by-products were reported to have higher live weights, litter size and weaning weights.

Pratap Reddy et al. (1989) reported that supplementation of basal ration with 75-100 g each of maize and GNC increased the DMI and ADG of weaner lambs. The feed efficiency was higher in lambs fed supplemented rations. The apparent digestibilities of CP, EE, NFE, hemicellulose and the DCP and TDN intake as well as N retention were higher in lambs fed 75-100 g each of maize and GNC as compared to those fed on basal ration.

A 2-year performance study involving Jamunapari goats in India revealed a drastic reduction in age at maturity to 359 days on basal roughage supplemented with a conventional concentrate mixture in comparison to those on browse which did not come to heat even after attaining 2 years of age (Krishna and Prasad, 1985).

Supplementation with urea at levels between 0.5 and 2.0% improved digestibility of nutrients present in the supplemented feed (Naga and El-Shazly, 1983). Remarkable improvement in the livestock gain, lamb survival and milk yield was reported by Stephenson et al. (1981) in ewes grazing on dry pastures and given urea mixed in drinking water.

Leibholz and Kellaway (1982) showed the effects of urea and energy supplementation on efficiency of bacterial protein synthesis, DMI and N flows in sheep fed on Paspalum hay (6.2 g N/kg DM). When urea was fed along with starch or sucrose there was 25% increase in forage DMI, 65% increase in N intake and 44% increase in bacterial protein synthesis.

2.4 ENRICHMENT OF CROP RESIDUES

Most of the crop residues and grass hays do not support the maintenance requirements of protein and energy when fed alone or unprocessed. Numerous efforts have been made to improve the nutritive value of crop residues by physical, chemical or biological methods. Upgrading of crop residues by chemical methods include treatment with alkalies, ammonia, urea/urine or a combination of above. Sommer (1981) surveyed various methods of physical and chemical treatment of straws for feeding cattle and reported that consumption of ammoniated straw was 17.4%

higher than that of untreated straw. Han and Garrett (1986) reported that urea, urine or ammonia treatments are one of the most practicable and beneficial ways to improve the feeding value of crop residues.

In India ammoniation of crop residues through urea treatment was found to be effective, practicable and economical since urea is available at low cost to the farmers and does not require a trained personnel for its adoption.

2.4.1 Ammoniation for improved performance

Jayasuriya and Perera (1982) concluded that 4% urea with ensiling period of 3 to 4 weeks has been the best method of treating rice straw. Digestibility *in vitro* was found to increase significantly with increase in the level of urea for 3 to 4 weeks treatments. Gupta *et al*. (1985) reported that 5% urea treatment with a storage period of 4 weeks was an effective way for improving the nutritive value of paddy straw.

Urea - wheat straw mixture in a 3.5 : 96.5 ratio was stacked with 40, 50, 60 and 70% moisture for 9 days by Bakshi *et al*. (1986). By 9th day the decline in cellulose and hemicellulose contents followed the increase in moisture level. The results of the study divulged that for ammonia treatment with urea, low moisture and urea levels with short stocking of 9 days were more suitable than high urea and 28 days stacking.

Jaikishan *et al.* (1987) attempted ammoniating paddy straw with or without molasses using 1 to 5% urea levels for periods varying from 1 to 5 weeks. Urea treatment at 5% level raised the CP content 3 times and rendered about 60% of N of the ammonia treated paddy straw in water soluble form. The moisture content of 38% and incubation at 38°C favoured optimum ammoniation. The *in sacco* DM digestibility was reported to be highest in ammoniated straw with 5% urea in contrast to 3% urea treatment.

The CP content of rice straw treated with 5% urea for 3 days was lower compared to that of 10 and 20 days storage which was attributed to undegraded urea remaining intact. However, Saadullah *et al.* (1988) stated that the intact urea will be available with the straw in the rumen which can be made use of by the rumen microbes once the straw is eaten.

Yadav and Yadava (1988) treated wheat straw and chaffed paddy straw with five concentration gradients of urea (0, 3, 4, 5 and 6 g per 100 g straw), four moisture gradients (30, 40, 50 and 60% of straw) and four treatment periods (1, 2, 3 and 4 weeks). The results of *in vitro* studies disclosed that a combination of 4% urea at 30% moisture level and 4 week treatment was optimum and suitable for ammoniation of wheat and paddy straws.

Digestibility of hay in sheep did not differ among moisture levels of 14, 25 and 35% but was significantly increased by ammonia treatment.

Mattoo _et al_. (1986a) treated chaffed paddy straw samples with 0, 4, 5 and 6% urea at 50% moisture level and stored for a period of 1, 2, 3 and 4 weeks to generate ammonia to interact with paddy straw. Significantly higher CP content of 22.5% was reported for samples treated with 6% urea at 4th week of storage compared to 16.89% with 5% urea level and 3.61% with untreated sample.

Urea treatment increased the CP content by 100.9 and 159.2% by stacking and ensiling, respectively (Reddy _et al_., 1988). Mikami _et al_. (1986) reported that the quantity of ammonia which was adhered firmly to wheat straw increased proportionately with moisture content up to 30% in straw and 20% in hay.

Venkataramana _et al_. (1989) treated bajra stalks with 4 levels of urea, 3 moisture gradients and incubated for a period of 10, 20 and 30 days. Level of urea did not influence the proximate components except CP and cell-wall constituents of bajra stalks. Highest CP (11.9%) was observed for the bajra stalks treated with 5% urea at 30% moisture for 10 days. The IVDMD increased from 19.6 to 29.2% with 4% urea treatment of straw moistened to 30% and incubated for 20 days. Urea treatment increased the DM disappearance of bajra stalks up to 4% level with the highest soluble DM fraction of 10% and EDDM of 28.08% as compared to 18.40% for the untreated stalks.

2.4.3 Effect of ammoniation on chemical composition

Ammoniation decreased the concentration of hemicellulose in Tall Fescue hay by 5.2% units and increased the total N from 1.27 to 2.61% (Buettner et al., 1982). It was further reported that ammoniation has significantly reduced ester bond absorbance and increased amide bond absorbance in the fibre fraction of the hay resulting from the breaking of ester bonds through aminolysis. The lower NDF of the treated hay presumably reflected on the decrease in hemicellulose and lignin contents associated with ammoniation. Apparently, these constituents were partially solubilized by ammoniation.

Ammoniation through 4% urea treatment at 30% moisture level for 4 weeks increased the CP content of wheat straw from 3.17 to 8.64% and paddy straw from 5.24% to 12.17% (Yadav and Yadava, 1986a). Rahman et al. (1987) sprinkled 4% aqueous urea solution over 100 kg of wheat straw at moisture level of 55%. After 4 weeks storage the CP content of treated straw was 9.53% as against 2.39% for untreated straw.

Toro and Majgaonkar (1987) reported a 3-fold increase in the CP content of paddy straw when treated with urea for 30 days. Urea treatment decreased the CF and NFE of paddy straw from 32.60 to 30.62% and 44.16 to 39.83%, respectively due to loss of lignin through solubilization by ammoniation.

Urea treatment promoted major chemical changes in the composition of cell walls in 2 Meadow hay samples (H_1 and H_2) when treated with 6% urea at 25°C for 3, 6, 9, 45 and 60 days. Concentrations of NDF, hemicellulose and lignin have been reduced significantly with increase in cellulose content. These effects were increased by treatment time. Concomittantly, the amount of soluble phenolics increased and the number of saponifiable groups reduced. Consequently, IVNDFD and IVOMD were significantly increased. After 60 days of storage urea treated samples showed an increase in total N content from 16.4 and 12.1 to 28.9 and 29.8 g/kg DM for H_1 and H_2, respectively (Mascarenhas-Ferreira et al., 1989).

The effect of urea (5%) as a source of ammonia on chemical composition of sorghum hay was studied by Reddy et al. (1993). Urea treatment has increased the CP and ash levels by 111 and 14% and decreased NDF, hemicellulose, ADF and ADL by 10, 18, 5 and 20%, respectively. However, urea treatment did not influence the CF and cellulose contents.

2.4.4 Effect of ammoniation on rumen degradability

Singh (1986) reported that nylon bag digestibility of treated wheat straw was higher than the untreated straw irrespective of temperature and days of storage. Significantly higher degradabilities of DM and protein were recorded by Dutta et al. (1988) with increasing levels of urea and periods of storage. The values of straws treated with 6% urea stored for 6 weeks and untreated straw were 65.26, 54.95 and 30.26, 3.40%, respectively at 36 hours of incubation in fistulated bullocks.

Chaffed paddy straw samples were treated with 0, 4, 5 and 6% urea at 50% moisture level and incubated for a period of 1, 2, 3 and 4 weeks by Mattoo et al. (1986b). Significantly higher DM and CP degradabilities were recorded with increasing concentration of urea compared to untreated straw. With increase in weeks of storage and hours of incubation a corresponding linear increase in both DM and protein degradabilities were also recorded.

Ramanaiah and Krishna (1993) studied the effect of urea treatment on DM and protein degradabilities of paddy straw using nylon bag technique. Urea treatment increased the soluble DM and protein fractions of paddy straw with an increase in insoluble but degradable fraction of protein by 100%. These effects have inturn increased the EDDM value from 34 to 40% and EDP value from 4 to 64%. In a similar study Ramana et al. (1990) observed an increase in EDP value from 27 to 59% due to urea treatment in treated bajra stalks. The effect of urea treatment was further felt through increase in EDDM value by 18.5% with paddy straw in comparison to an increase of 5.3% in pearl millet straw as reported by Venkataramana et al. (1989).

Reddy et al. (1993) fitted the nylon bag data of sorghum hay treated with 5% urea to the model of $P = a + b\ (1-e^{-ct})$ and reported that the rate (c) constant and extent of degradabilities (a + b) were increased by urea treatment.

2.4.5 Effect of ammoniation on DM intake and animal performance

In trials with crossbred steers Wanapat et al. (1983) observed increase in daily DM intake from 4.93 kg per head without urea treatment to 6.82 kg when urea was used in ensilage for 3 weeks. In another study urea treatment has been found to improve rice straw from a submaintenance to a maintenance ration for buffaloes (Wanapat et al., 1984).

Feeding of rice straw ensiled with 4% urea to Sahiwal heifers over a period of 10 weeks divulged higher intake for ensiled straw than untreated straw (Perdok et al., 1984).

Singh and Barsaul (1985) reported significantly higher digestibility coefficients for DM, EE, CF and NFE of the ration containing urea treated wheat straw with reduced intake of concentrate mixture by 63% as compared to feeding untreated straw without any effect on CP digestibility.

Yadav and Yadava (1986a) conducted a growth trial using crossbred male calves by feeding untreated or ammoniated wheat straw or paddy straw with varying levels of concentrate mixture. Digestibilities of DM, OM, hemicellulose, CF, NDF, ADF, lignin and cellulose increased in animals fed ammoniated straw.

Attempts were made by Rahman et al. (1987) to improve the palatability and nutritive value of wheat straw by urea treatment. Digestibility coefficients for DM, CP, EE, CF and NFE were 48.15, 67.04, 64.65, 59.07 and 44.95, respectively with DCP and TDN values of 6.36 and 47.98%, respectively for treated straw which was comparable to any maintenance type non-legume forage.

Three groups of Nellore rams were fed untreated, 4 and 5% urea treated bajra straws ad libitum + 150 g concentrate pre-mix (Venkataramana et al., 1989). Urea treatment at 4 and 5% levels increased total DMI from 51 to 57 and 61 g/kg $W^{0.75}$/day, respectively. Ammoniation through 4 and 5% urea treatments significantly increased the digestibilities of CP, CF, NDF, ADF, hemicellulose, cellulose, lignin and TDN and DCP intakes. Urea treatment significantly increased the N retention and differences in the N retention of rams fed 4 and 5% urea treated straw based rations were however non-significant.

Puri and Gupta (1990) fed 3 groups of crossbred calves with untreated, 4% urea + 40% moisture and 5% urea + 30% moisture treated rice straws with concentrate mixture and reported that the mean live weight gains (g/day) were 416.67, 562.50 and 541.67, respectively. The apparent digestibilities of DM, CF, NDF, ADF and cellulose were significantly higher in animals fed treated straws as compared to those fed untreated straw. However, the digestibility of CP was not affected. The TDN and ME intakes increased significantly in ammoniated rice straw fed animals.

Feeding of untreated paddy straw and urea treated straw plus concentrate mixture at 100, 75 and 50% maintenance requirements to cows increased the DMI by 25, 45 and 36% and milk yield by 18, 40 and 38%, respectively (Deepak Kumar et al., 1991). The cost of milk production has been reported to be reduced by 6, 3 and 26%, respectively due to inclusion of urea treated paddy straw in the rations.

Two equal groups of crossbred heifers were fed hill dry grass and grass treated with 4% urea - ammonia ad libitum at 50% moisture along with 1-1.25 kg concentrate mixture for 60 days. The digestibility coefficients of nutrients of urea treated grass rations were higher than in the untreated ration. The TDN values of untreated and urea treated grass rations were 47.58 and 53.70% and the DCP values 5.03 and 10.28%, respectively. The DM intake of urea treated grass rations were higher than that of untreated grass ration. Feeding of urea treated grass resulted in higher weight gain and reduced the cost/kg live weight gain of heifers as compared to those fed with untreated grass ration (Singh and Taparia, 1992).

CHAPTER - III

3. MATERIALS AND METHODS

3.1 PROCUREMENT OF INGREDIENTS

Cenchrus ciliaris (Anjan) grass hay was procured from the Department of Feed and Fodder Technology, College of Veterinary Science, Tirupati. The hay was chopped and ground to give particles of uniform size in a chopper-cum-grinder and stored in gunny bags till it was subjected to urea treatment.

Fertilizer grade urea (Jaikisan brand) was purchased locally for ammoniation of Cenchrus hay. Solvent extracted palm kernel cake was purchased from M/s Shreela Agro-Traders, Guntur. Rest of the feed ingredients were purchased from the Andhra Pradesh Meat and Poultry Development Corporation, Chittoor.

3.2 UREA TREATMENT OF CENCHRUS HAY

3.2.1 Laboratory scale ammoniation

Cenchrus hay was subjected to urea treatment in round bottomed 2 L capacity screw capped plastic jars to optimise the standard conditions of moisture level and period of incubation. Moisture levels of 30, 40 and 50%

and incubation periods of 10, 15 and 20 days were choosen keeping the urea level constant at 4% to select the effective level of moisture and period of incubation for _in vivo_ evaluation studies.

For initial screening, 500 g of Cenchrus hay treated with 4% urea at three moisture levels was tightly packed in each jar and screw capped. Based on the original moisture content of Cenchrus hay, 4 g of fertilizer grade urea was dissolved in 28, 49 and 79 ml of water to treat 100 g each of ground Cenchrus hay to attain final moisture levels of 30, 40 and 50%, respectively, for treating Cenchrus hay samples. The jars were opened at the end of 10, 15 and 20 days and moisture content was determined prior to collection of materials for further analysis. The dried samples were ground in a Wiley mill using medium mesh (2 mm) screen and were sealed in polyethene bags till analysis was carried out.

Based on the results of preliminary investigation carried out with urea level of 4 per cent, optimum moisture level of 40% and incubation interval of 10 days were selected for detailed _in vivo_ evaluation studies. 50 L capacity circular concrete tubs were used to treat Cenchrus hay in bulk for animal experimentation.

Twenty kilograms of Cenchrus hay treated with 4% urea was tightly packed in each tub. To each 20 kg of Cenchrus hay 800 g of urea dissolved in 9.8 litres of water was used to obtain urea concentration of 4% in the solution. The treated material was covered with black polythene sheet all around and at the top before sealing. At the end of 10 days incubation the tubs were opened and the treated Cenchrus hay was exposed to open air overnight prior to feeding on the next day to minimize the effect of residual ammonia entrapped in the treated straw on the health status of the experimental animals.

3.3 *IN VITRO* EVALUATION OF EXPERIMENTAL RATIONS

Cenchrus hay either untreated or treated with 4% urea at 30, 40 and 50% moisture levels for 10, 15 and 20 days of incubation were subjected to two-stage *in vitro* dry matter digestibility technique of Tilley and Terry (1963). Each sample was evaluated in duplicate using 0.5 g ground samples. Rumen liquor was collected from a permanently rumen cannulated Nellore Brown ram kept on a standard all forage ration.

3.4 *IN SITU* DRY MATTER DISAPPEARANCE OF CENCHRUS HAY

In situ DM disappearance of Cenchrus hay treated with 4% urea at a moisture level of 40% for 10 days was determined using the nylon bag technique (Kempton, 1980). Bags made of nylon cloth (25-28 microns mesh size) with a 21 cm^2 bag area/g dry matter of the sample were used.

Permanently cannulated 4 Nellore Brown yearling rams (23.50 ± 1.14 kg) fitted with ice bags as rumen plugs were used for *in sacco* evaluation studies. The rams were maintained on 0.5 kg of concentrate mixture and 0.5 kg of Cenchrus hay through out the study to maintain a constant rumen outflow rate.

Air dried hay samples were ground in a laboratory Wiley mill using a medium mesh screen of 2 mm. The ground materials were stored in air-tight screw capped plastic bottles. Each nylon bag was closed and secured with a nylon fishing line after placing a glass marble in it to prevent floating in the rumen digesta during rumen fermentation. The strings were color coded for identification of the bags at the time of removal.

Three grams of samples were weighed into each of five bags and incubated in the ventral sac of the rumen of each ram with the aid of 40 cm nylon string secured to each bag to allow free movement of bags with in the rumen. At the end of 12, 24, 36, 48 and 72 h incubation the bags were removed from the rumen of each ram. The surface of the bags were washed under tap and dried to a constant weight at 70^{o}C for 48 h in a forced draft oven and per cent DM disappearance was determined. The constants a, b and c were derived by fitting a curve by eye to the data points by simple algebra (Orskov *et al.*, 1980) and the effective degradable dry matter of Cenchrus hay samples were calculated using an assumed outflow rate (k) value of 0.05/h.

3.5 NUTRIENT UTILIZATION AND NITROGEN BALANCE STUDIES

To find out the effect of urea treatment with or without PKC supplementation, each of the 4 yearling Nellore Brown ram lambs was fed either untreated or urea treated Cenchrus hay with or without PKC supplementation. The rations were evaluated in a 4 x 4 latin square nitrogen balance experiment using ram lambs of average body weight of 15,00±1.02 kg. The ram lambs were dewormed with Panacur (Hoechst India Ltd.) before the start of the experiment. A 10-day preliminary period and 7-day collection period were followed during the metabolism trials. The ram lambs were confined to individual pens of 2 m x 1 m with facilities for individual feeding and watering during the preliminary period and were shifted to metabolism cages two days prior to and during the collection period.

The respective rations were offered at 3% of their body weight to meet the energy and protein requirements as per Kearl (1982) at 8 AM daily along with 5 g mineral mixture and 0.25 g Vitablend (AD_3). The live weights of the ram lambs were recorded before the start and at the end of each period consecutively for 3 days. Body weights were recorded prior to offering feed and water at fixed time through out the studies. Fresh drinking water was made available and a record of daily water consumed by each animal was maintained. During each period of the metabolism trial 24 h collection of faeces was made using faeces bags harnessed to the ram lambs. The daily urine out put of each lamb was measured by collecting in glass bottles kept at the bottom of each metabolism cage. Few drops of concentrated HCl were added to urine collection bottles daily as a preservative.

3.6 COLLECTION OF SAMPLES

3.6.1 Feed

Samples of Cenchrus hay supplemented with 100 g of palm kernel cake were collected daily and composited for each collection period. Daily aliquot from untreated and urea treated Cenchrus hay offered and left over on each day were collected and composited in polyethene bags and frozen in a refrigerator. The DM content of the samples were determined daily. At the end of the collection period representative samples were oven dried and ground through a Wiley mill and placed in air-tight bottles for further analysis.

3.6.2 Faeces

Faeces voided by each lamb during 24 h was weighed at 8 AM and a 10% aliquot was composited in polyethene bags and frozen in a refrigerator. Dry matter content of the faeces was determined daily. At the end of the collection period representative faecal samples were oven dried and ground through a medium mesh (2 mm) screen of Wiley mill.

3.6.3 Urine

Urine voided by individual lambs during 24 h was measured at 8 AM and a 5% aliquot of urine was composited and preserved with 2 ml of concentrated HCl in glass bottles and kept in a refrigerator till analysed for nitrogen content.

3.7 CHEMICAL ANALYSIS

Samples of untreated and urea treated Cenchrus hay and palm kernel cake were analysed for proximate principles (AOAC, 1985). Samples of fresh faeces and aliquots of urine were used to determine the nitrogen content by Kjeltec 1026 (Tecator, Sweden). The cell-wall constituents of Cenchrus hay (untreated and treated), palm kernel cake, feed left-over and faeces were determined as per the procedures of Goering and Van Soest (1970).

3.8 STATISTICAL ANALYSIS

The data were subjected to analysis of variance (Snedecor and Cochran, 1968). The treatment means were tested for significance by Duncan's new multiple range test (Duncan, 1955).

CHAPTER - IV

4. RESULTS

4.1 CHEMICAL COMPOSITION

4.1.1 Cenchrus grass hay

Chemical composition of Cenchrus hay used in the present study is presented in Table 1. On DM basis, Cenchrus hay contained 3.89% crude protein (CP), 1.38% ether extract (EE), 31.84% crude fibre (CF), 52.97% nitrogen free extract (NFE) and 9.92% total ash. Fractionation of cell-wall constituents using detergent system of analysis showed 70.98% neutral detergent fibre (NDF), 39.45% acid-detergent fibre (ADF), 31.53% hemicellulose, 28.91% cellulose, 8.11% lignin and 2.43% silica on DM basis.

4.1.2 Urea treated Cenchrus hay

To standardise the technique of urea treatment adoptable to Cenchrus hay, effective level of moisture and optimum period of incubation were determined initially prior to *in vivo* evaluation. Moisture levels of 30, 40 and 50% at a standard urea level of 4% were selected to incubate 500 g of chopped and ground Cenchrus hay in 2 L capacity screw capped plastic jars for a period of 10, 15 and 20 days.

Table 1. Chemical composition of Cenchrus hay

Nutrient	%
Dry matter	89.34
Crude protein	3.89
Ether extract	1.38
Crude fibre	31.84
Nitrogen free extract	52.97
Total ash	9.92
Neutral detergent fibre	70.98
Acid detergent fibre	39.45
Hemicellulose	31.53
Cellulose	28.91
Permanganate lignin	8.11
Silica	2.43

On dry matter basis except for dry matter

The effect of varying levels of moisture and incubation intervals on chemical composition of 4% urea treated hay was studied and the data are presented in Table 2. Among the several chemical constituents considered, CP content alone showed marked increase when treated with urea. Addition of 4% urea raised the CP content of Cenchrus hay from 3.89% to a maximum level of 14.27% when incubated at 40% moisture for 15 days. Lower CP value of 11.43% was observed with urea treatment of hay at 50% moisture level for 10 days. It was further observed that the CP content increased when the moisture level was increased from 30 to 40% followed by a decrease with further increase in the moisture level to 50%.

A decreased trend in NDF content of urea treated Cenchrus hay was observed as the period of incubation increased from 10 to 20 days. The differences in the chemical composition of other cell-wall constituents were negligible.

4.2 OPTIMUM LEVELS OF MOISTURE AND INCUBATION

The effective level of per cent moisture and period of incubation were selected based on the average values of CP and IVDMD.

4.2.1 Level of moisture

The effect of moisture level on the average CP and cell-wall constituents of urea treated Cenchrus hay was

Table 2. Effect of level of moisture and incubation interval on chemical composition (%) of 4% urea treated Cenchrus hay

	Incubation interval (days)								
	10			15			20		
	Moisture (%)								
	30	40	50	30	40	50	30	40	50
DM	71.38	61.01	52.12	71.44	61.86	51.58	71.55	61.67	52.00
CP	13.11	14.04	11.43	12.37	14.27	11.58	12.10	13.50	11.71
NDF	69.73	68.32	70.36	68.24	67.18	68.90	66.56	66.37	67.29
ADF	41.53	39.34	42.76	39.72	40.21	40.78	38.31	39.64	40.16
Hemicellulose	28.20	28.98	27.60	28.52	26.97	28.12	28.25	26.73	27.13
Cellulose	30.90	29.76	32.57	30.19	30.69	31.28	29.87	30.35	31.58
Permanganate lignin	7.81	6.92	7.70	7.39	7.10	6.55	6.24	7.20	6.60
Silica	2.82	2.66	2.49	2.14	2.42	2.95	2.20	2.09	1.98

On dry matter basis except for dry matter
Each value is the average of duplicate analysis

studied and the data are presented in Table 3. Significantly ($P < 0.01$) higher CP of 13.94% was observed for hay subjected to 40% moisture as compared to 12.53 and 11.57% for 30 and 50% moisture levels, respectively on DM basis. The average per cent NDF, ADF, hemicellulose, cellulose, lignin and silica values of Cenchrus hay treated with 30, 40 and 50% moisture levels were 68.18, 39.85, 28.32, 30.32, 7.15, 2.39; 67.29, 39.73, 27.56, 30.27, 7.07, 2.39 and 68.85, 41.23, 27.62, 31.81, 6.95 and 2.47, respectively irrespective of period of incubation used. However, the values were not significantly different from each other.

4.2.2 Period of incubation

The data indicating the effect of incubation period on the average CP and cell-wall constituents of urea treated Cenchrus hay are presented in Table 4. The average CP content of hay treated with 4% urea and incubated for 10, 15 and 20 days were 12.86, 12.74 and 12.44%, respectively irrespective of the level of moisture used. The average NDF, ADF, hemicellulose, cellulose, lignin and silica values of Cenchrus hay incubated for 10, 15 and 20 days were 69.47, 41.21, 28.26, 31.10, 7.48, 2.66; 68.11, 40.24, 27.87, 30.72, 7.01, 2.50 and 66.74, 39.37, 27.37, 30.60, 6.68 and 2.09%, respectively on DM basis irrespective of moisture level used. However, the values of CP and cell-wall constituents were not significantly different from each other.

Table 3. Effect of level of moisture on chemical composition (%) of urea treated Cenchrus hay

Nutrient	Moisture (%)		
	30	40	50
CP	12.53[b] ± 0.30	13.94[c] ± 0.23	11.57[a] ± 0.10
NDF	68.18 ± 0.92	67.29 ± 0.57	68.85 ± 0.89
ADF	39.85 ± 0.93	39.73 ± 0.26	41.23 ± 0.78
Hemicellulose	28.32 ± 0.10	27.56 ± 0.71	27.62 ± 0.29
Cellulose	30.32 ± 0.30	30.27 ± 0.27	31.81 ± 0.39
Permanganate lignin	7.15 ± 0.47	7.07 ± 0.10	6.95 ± 0.38
Silica	2.39 ± 0.22	2.39 ± 0.17	2.47 ± 0.28

Each value is the average of 6 observations

[abc]Values in the row bearing different superscripts differ significantly ($P < 0.01$)

Table 4. Effect of duration of incubation on chemical composition (%) of urea treated Cenchrus hay

Nutrient	Days		
	10	15	20
CP	12.86 ± 0.76	12.74 ± 0.80	12.44 ± 0.54
NDF	69.47 ± 0.60	68.11 ± 0.50	66.74 ± 0.28
ADF	41.21 ± 1.00	40.24 ± 0.31	39.37 ± 0.55
Hemicellulose	28.26 ± 0.40	27.87 ± 0.46	27.37 ± 0.45
Cellulose	31.10 ± 0.82	30.72 ± 0.32	30.60 ± 0.51
Permanganate lignin	7.48 ± 0.28	7.01 ± 0.25	6.68 ± 0.28
Silica	2.66 ± 0.10	2.50 ± 0.24	2.09 ± 0.10

Each value is the average of 6 observations

Values in the rows did not differ significantly ($P > 0.05$)

4.3 *IN VITRO* EVALUATION

The effect of level of moisture and period of incubation on the digestibility of DM was studied in terms of *in vitro* dry matter digestibility (IVDMD). The average per cent IVDMD values of urea treated Cenchrus hay subjected to varying levels of moisture and incubation periods are presented in Table 5. The IVDMD value was 43.10% and highest for hay subjected to 40% moisture and incubated for 20 days as compared to 27.68% for untreated hay. The IVDMD value increased ($P < 0.01$) from 40.03% to 42.59% upto 40% moisture level in the treated hay. Further increase in the level of moisture to 50% decreased the IVDMD value to 39.05%. The average IVDMD value increased ($P > 0.05$) from 40.09 to 41.07% as the period of incubation was extended from 10 to 20 days.

4.4 *IN SACCO* EVALUATION STUDIES

The semi *in vivo* nylon bag technique offers the possibility of measuring the extent of DM degradation of feed stuffs at specific intervals of time, since the values simulate the fermentation that normally occurs in the rumen.

The *in sacco* DM disappearance of 4% urea treated hay was determined by nylon bag technique in an attempt to further evaluate the urea treated hay subjected to varying levels of moisture and periods of incubation.

Table 5. Effect of level of moisture and incubation interval on IVDMD of 4% urea treated Cenchrus hay

Incubation interval (days)	Moisture (%) 30	40	50	Overall mean
10	39.01	41.98	39.27	40.09 ±0.95
15	40.33	42.68	38.52	40.51 ±1.20
20	40.76	43.10	39.35	41.07 ±1.09
Overall mean	40.03[a] ±0.54	42.59[b] ±0.33	39.05[a] ±0.26	

Each value is the average of duplicate analysis

[ab]Values in the row bearing different superscripts differ significantly ($P < 0.01$)

4.4.1 *In sacco* DM disappearance

Data on the effect of level of moisture and period of incubation on DM disappearance of Cenchrus hay are presented in Table 6. The pattern of disappearance of DM of urea treated hay from the nylon bags incubated in the rumen of fistulated Nellore Brown yearling rams is shown in Figure II, III and IV in comparison to that of untreated hay (Figure I). The average *in sacco* DM disappearance of untreated hay was 25.10, 34.97, 42.33, 47.46 and 51.11%, respectively at 12, 24, 36, 48 and 72 hrs of incubation in the rumen. Lowest DM disappearance values were observed at 50% moisture level when incubated for 15 days while the values were highest at 40% moisture level when incubated for 20 days. It was further observed that the per cent DM disappearance increased as the moisture level increased from 30 to 40%. However, the values decreased when the moisture level was further increased to 50% except for hay incubated for 10 days.

4.4.2 Level of moisture

The effect of level of moisture on the average *in sacco* DM disappearance of urea treated Cenchrus hay was studied and the data are presented in Table 7. Significantly higher (P 0.01) value of 52.13% was observed for hay subjected to 40% moisture level as compared to 48.76% observed with 30% moisture and 47.80% with 50% moisture level.

Table 6. Effect of level of moisture and period of incubation on *in situ* DM disappearance (%) of urea treated Cenchrus hay

Incubation interval (h)	Untreated Cenchrus hay	Period of incubation (days)								
		10			15			20		
		Moisture (%)								
		30	40	50	30	40	50	30	40	50
12	25.10 ±1.14	33.65 ±1.01	36.92 ±1.48	34.10 ±1.12	35.08 ±1.38	37.60 ±1.41	33.16 ±1.47	36.12 ±1.35	38.20 ±0.81	34.92 ±1.10
24	34.97 ±1.39	40.34 ±0.68	44.46 ±0.97	40.78 ±0.83	42.26 ±1.13	45.21 ±0.76	39.81 ±1.16	43.23 ±1.55	45.98 ±0.84	41.96 ±0.55
36	42.33 ±1.29	47.80 ±1.23	52.11 ±1.52	48.40 ±1.31	49.36 ±1.61	52.84 ±0.82	47.24 ±0.84	50.13 ±0.51	53.26 ±0.93	49.04 ±1.60
48	47.46 ±0.97	54.15 ±1.09	58.82 ±0.74	55.18 ±0.68	56.26 ±0.91	59.57 ±0.23	53.60 ±1.88	57.00 ±0.82	60.17 ±1.28	55.64 ±0.74
72	51.11 ±0.40	60.80 ±1.34	64.65 ±0.70	61.40 ±1.15	62.45 ±0.69	65.60 ±0.90	59.94 ±0.45	62.81 ±0.56	66.52 ±1.02	61.74 ±1.20

Each value is the average of 4 observations

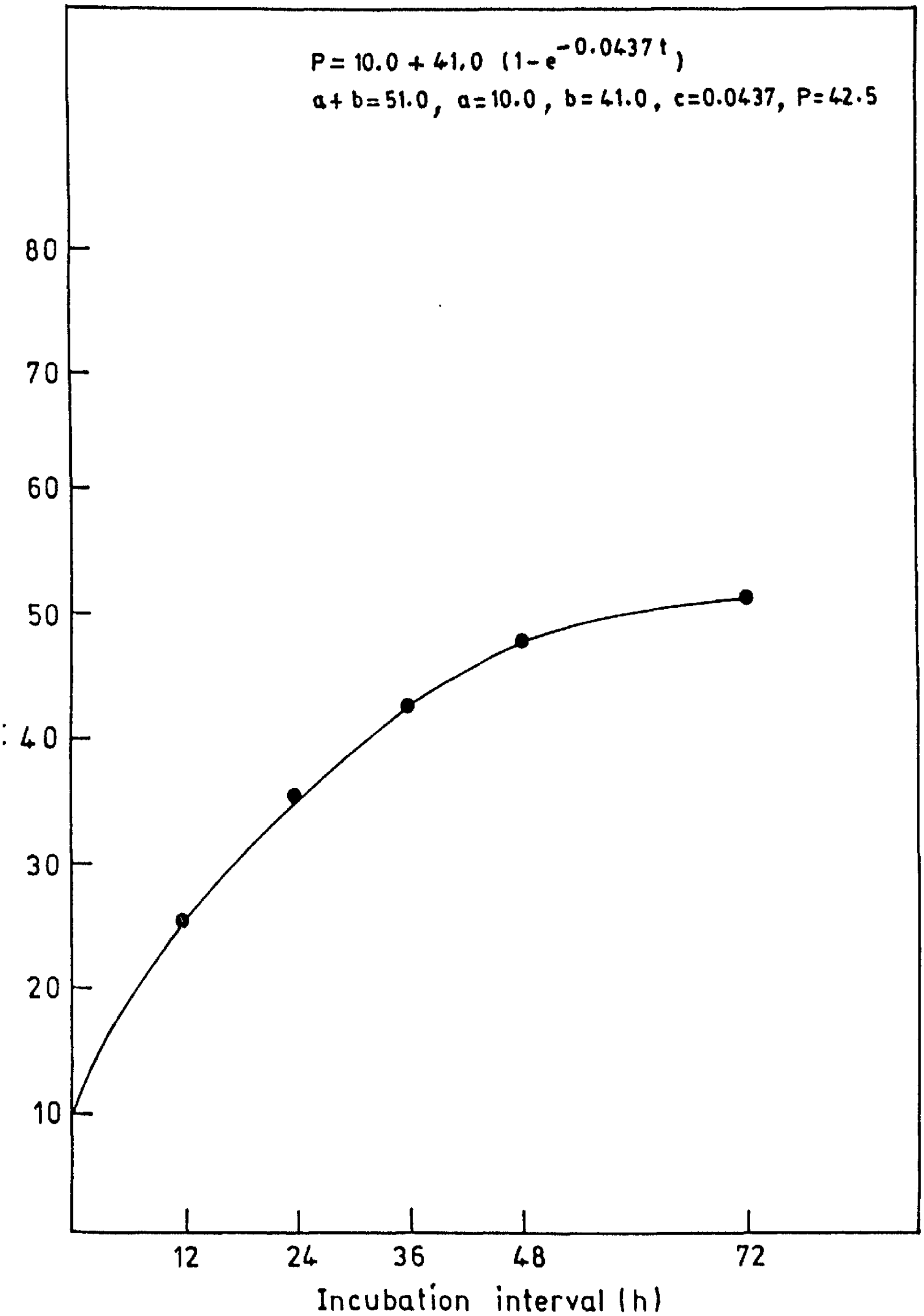

Fig.I *In sacco* DM disappearance of Cenchrus hay (untreated)

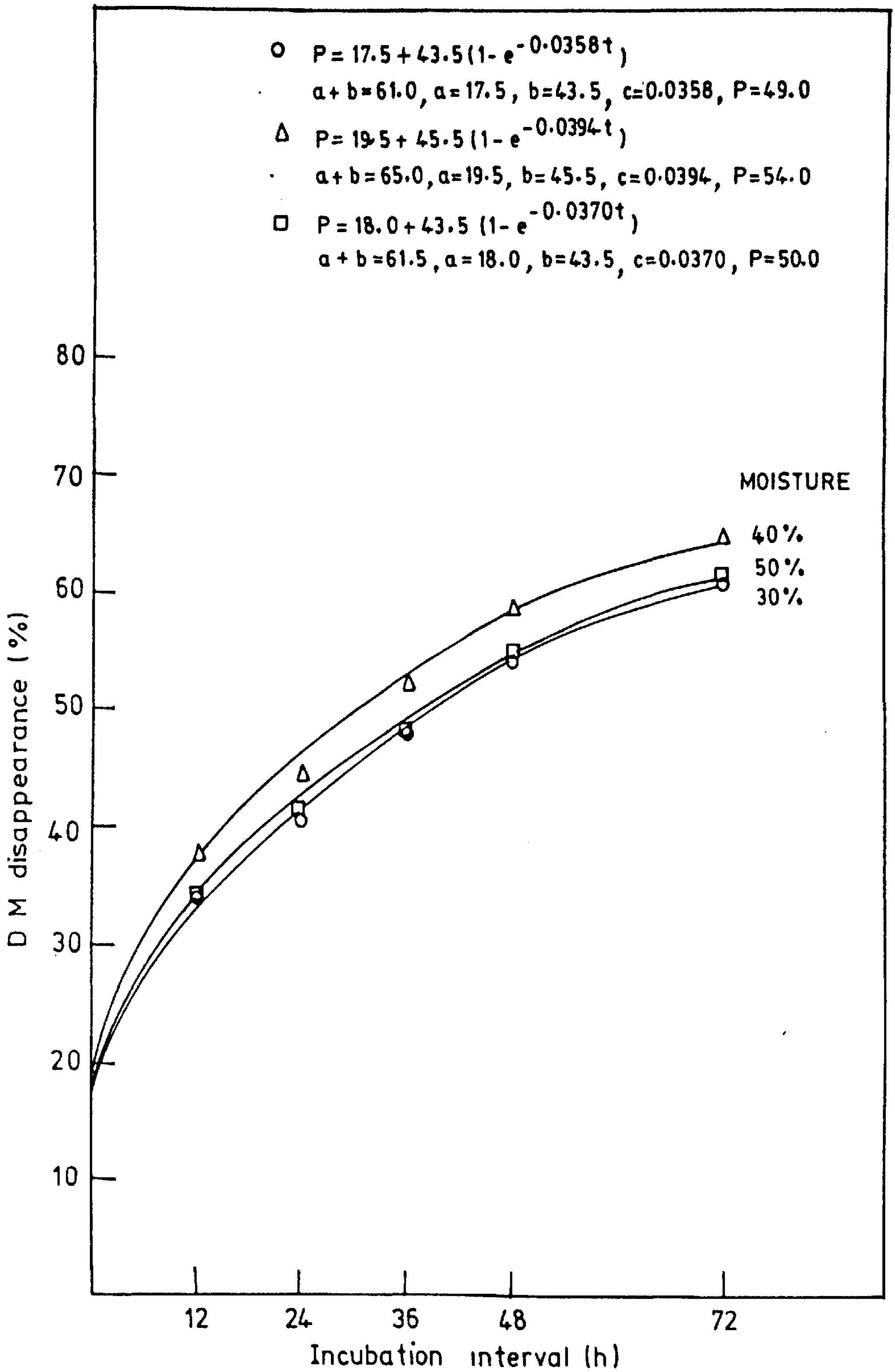

Fig. II Effect of moisture level on in sacco DM disappearance of Cenchrus hay treated with 4% urea for 10 days

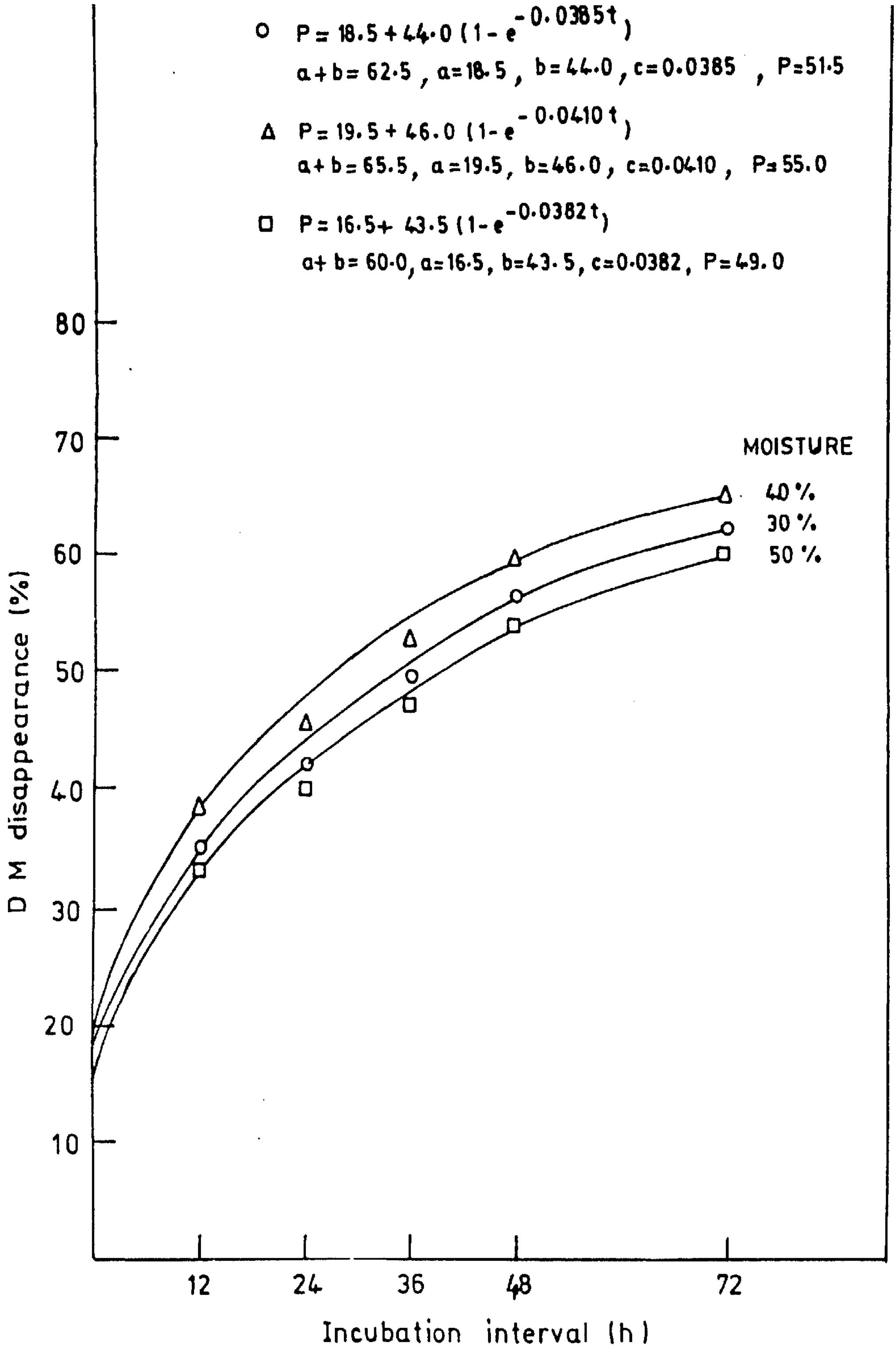

Fig. III Effect of moisture level on *in sacco* D M disappearance of Cenchrus hay treated with 4% urea for 15 days

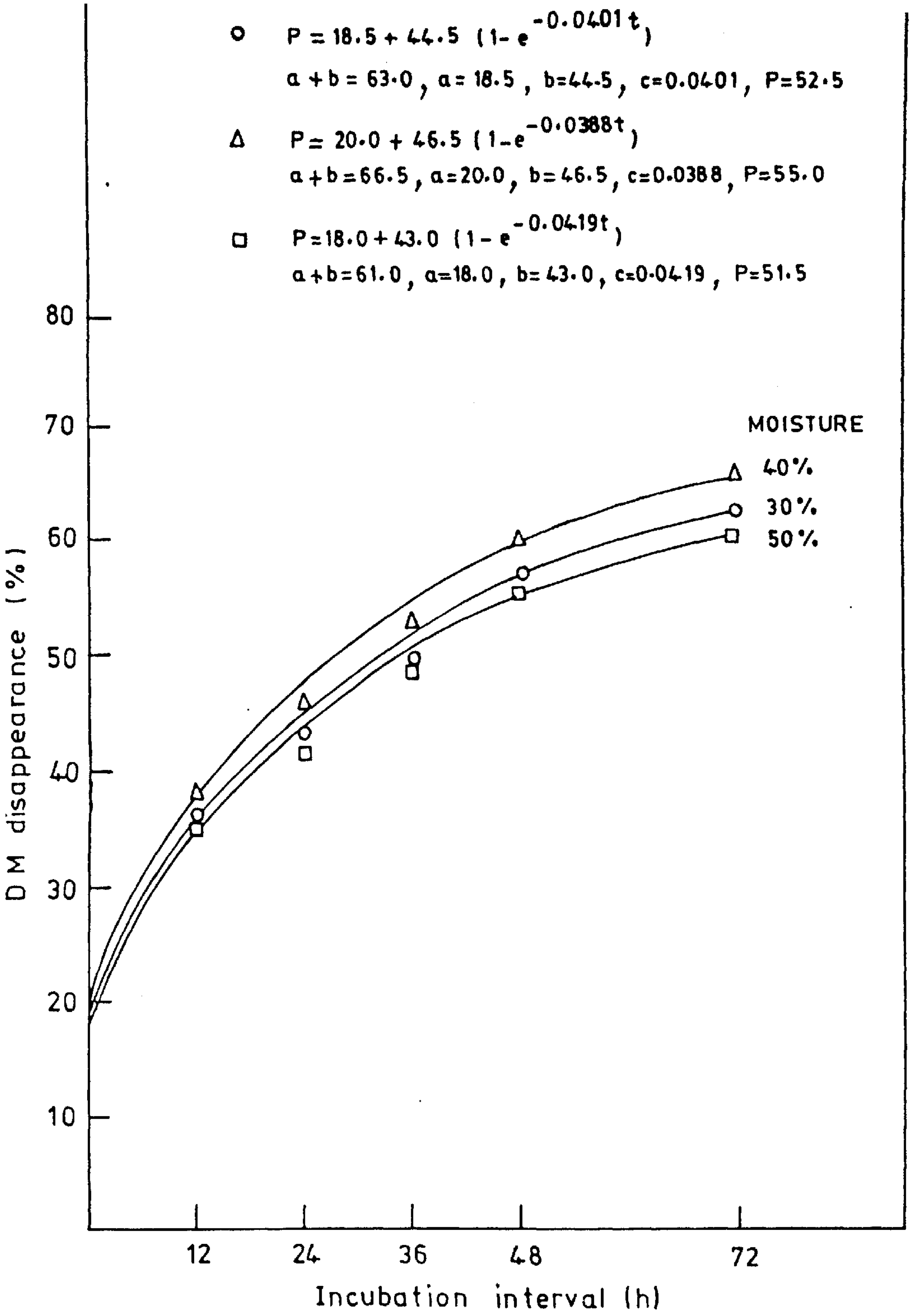

Fig. IV Effect of moisture level on in sacco D M disappearance of Cenchrus hay treated with 4% urea for 20 days

Table 7. Effect of level of moisture on average *in situ* DM disappearance (%) of urea treated Cenchrus hay

Incubation interval (h)	Moisture (%)		
	30	40	50
12	$34.95^{a} \pm 0.72$	$37.57^{b} \pm 0.37$	$34.06^{a} \pm 0.51$
24	$41.94^{a} \pm 0.85$	$45.22^{b} \pm 0.44$	$40.85^{a} \pm 0.62$
36	$49.10^{a} \pm 0.69$	$52.74^{b} \pm 0.34$	$48.23^{a} \pm 0.53$
48	$55.80^{a} \pm 0.85$	$59.52^{b} \pm 0.39$	$54.81^{a} \pm 0.62$
72	$62.02^{a} \pm 0.62$	$65.59^{b} \pm 0.54$	$61.03^{a} \pm 0.55$
Mean	$48.76^{a} \pm 4.81$	$52.13^{b} \pm 4.98$	$47.80^{a} \pm 4.80$

Each value is the average of 12 observations

[ab]Values in the rows bearing different superscripts differ significantly ($P < 0.01$)

4.4.3 Period of incubation

Data on the effect of period of incubation on the average in sacco DM disappearance of urea treated Cenchrus hay are presented in Table 8. The average DM disappearance values were 48.90, 49.33 and 50.45%, respectively for hay incubated for 10, 15 and 20 days. However, the values were not significantly different from each other.

4.4.4 Calculation of effective degradable dry matter

The constants 'a' (readily soluble), 'b' (insoluble but degradable with time) and 'c' (rate constant/h) for untreated and urea treated hays were derived by fitting a curve by eye to the data points of per cent in situ DM disappearance values (Table 9). The outflow rate (k) of 0.05/h was used to calculate the effective degradable dry matter (EDDM) using Orskov and McDonald (1979) model. The EDDM of untreated Cenchrus was calculated to be 29.12 with the a, b and c constants being 10.0, 41.0 and 0.0437, respectively to be considered as a poorly degradable roughage source. The soluble DM fraction 'a' was highest (20%) for 4% urea treated hay incubated for 20 days at 40% moisture level. Lowest 'a' value (16.5%) was observed for hay incubated for 15 days at 50% moisture level. The highest insoluble but degradable DM fraction 'b' (46.5%) was observed for hay incubated for 20 days at 40% moisture level and lowest value (43.5%) was observed for hay incubated for 15 days at 50% moisture level. The rate

Table 8. Effect of period of incubation on average *in situ* DM disappearance (%) of urea treated Cenchrus hay

Incubation interval (h)	Period of incubation (days)		
	10	15	20
12	34.89 ± 1.02	35.28 ± 1.29	36.41 ± 0.96
24	41.86 ± 1.31	42.43 ± 1.56	43.72 ± 1.19
36	49.44 ± 1.35	49.81 ± 1.63	50.81 ± 1.26
48	56.05 ± 1.42	56.48 ± 1.73	57.60 ± 1.34
72	62.28 ± 1.20	62.66 ± 1.64	63.69 ± 1.45
Mean	48.90 ± 4.88	49.33 ± 4.87	50.45 ± 4.84

Each value is the average of 12 observations

Values in the rows did not differ significantly ($P > 0.05$)

Table 9. Constants (a, b and c) and effective degradability (%) of dry matter (EDDM) of urea treated Cenchrus hay

Constants	Untreated Cenchrus hay	Incubation interval (days)								
		10			15			20		
		Moisture (%)								
		30	40	50	30	40	50	30	40	50
a	10.0	17.5	19.5	18.0	18.5	19.5	16.5	18.5	20.0	18.0
b	41.0	43.5	45.5	43.5	44.0	46.0	43.5	44.5	46.5	43.0
c	0.0437	0.0358	0.0394	0.0370	0.0385	0.0410	0.0382	0.0401	0.0388	0.0419
EDDM	29.12	35.65	39.55	36.50	37.64	40.23	35.34	38.28	40.32	37.61

a (soluble), b (insoluble but degradable) and c (rate constant/h) are constants

EDDM represents effective degradability of dry matter (Orskov and McDonald, 1979) at an assumed outflow rate (k) of 0.05/h constant/h of degradable dry matter 'c' increased when the moisture level was increased from 30 to 40% and decreased when the moisture level was further increased to 50% except for hay incubated for 20 days at different moisture levels. The EDDM value was highest (40.32%) for hay subjected to 40% moisture level and incubated for 20 days and the lowest value (35.34%) was observed at 50% moisture level when incubated for 15 days. However, the differences were negligible among values recorded for hay incubated for 10, 15 and 20 days at 40% moisture level.

Based on the results of chemical analysis, IVDMD and *in sacco* effective degradable dry matter estimations, moisture level of 40% and incubation period of 10 days were selected for treating the hay for *in vivo* evaluation studies.

4.5 *IN VIVO* EVALUATION STUDIES

In vivo evaluation studies were carried out to determine the nutritive value of Cenchrus hay and to find out the effect of supplementation of palm kernel cake to Cenchrus hay either untreated or treated with 4% urea at a moisture level of 40% for 10 days in a digestion-cum-nitrogen balance experiment involving 4 Nellore Brown weaner ram lambs in a 4 x 4 latin square design.

4.5.1 Chemical composition of feedstuffs

4.5.1.1 Urea treated Cenchrus hay

The average chemical composition of Cenchrus hay treated with urea is presented in Table 10. On fresh basis urea treated hay contained 59.70% dry matter. The CP content of urea treated hay was 14.04% as compared to 3.89% for untreated hay on DM basis. On DM basis, treated hay contained 1.40% EE, 29.97% CF, 44.11% NFE and 10.48% total ash. Analysis of cell-wall constituents disclosed the presence of 68.32% NDF, 39.34% ADF, 28.98% hemicellulose, 29.76% cellulose, 6.92% lignin and 2.66% silica in the treated hay on DM basis.

4.5.1.2 Palm kernel cake

Chemical composition of palm kernel cake (PKC) used in the present study is presented in Table 11. On DM basis, PKC contained 15.05% CP, 1.21% EE, 30.35% CF, 44.49% NFE and 8.90% total ash. Cell-wall constituents of PKC included 74.37% NDF, 41.58% ADF, 32.79% hemicellulose, 22.03% cellulose, 17.41% lignin and 2.14% silica on DM basis.

4.5.1.3 Urea as a source of NPN

The N content of urea used in the present study for ammoniation of Cenchrus hay was 47.02% on DMB.

Table 10. Chemical composition (%) of Cenchrus hay treated with 4% urea at 40% moisture level and incubated for 10 days

Nutrient	%
Dry matter	59.70
Crude protein	14.04
Ether extract	1.40
Crude fibre	29.97
Nitrogen free extract	44.11
Total ash	10.48
Neutral detergent fibre	68.32
Acid detergent fibre	39.34
Hemicellulose	28.98
Cellulose	29.76
Permanganate lignin	6.92
Silica	2.66

On dry matter basis except for dry matter

Table 11. Chemical composition (%) of Palm kernel cake (PKC)

Nutrient	%
Dry matter	91.80
Crude protein	15.05
Ether extract	1.21
Crude fibre	30.35
Nitrogen free extract	44.49
Total ash	8.90
Neutral detergent fibre	74.37
Acid detergent fibre	41.58
Hemicellulose	32.79
Cellulose	22.03
Permanganate lignin	17.41
Silica	2.14

On dry matter basis except for dry matter

4.5.2 Effect of feeding on dry matter intake of lambs

Nellore Brown weaner ram lambs were fed rations containing untreated hay, untreated hay supplemented with PKC (100 g), urea treated hay or treated hay supplemented with PKC (100 g) to provide total DM at 3% of body weight and to meet the energy and protein requirements as per Kearl (1982).

The daily DM intake from roughage and PKC components were calculated and presented in Table 12. The DM intake from Cenchrus hay, expressed as g/day or g/kg $W^{0.75}$/day was 422.80, 53.80; 341.25, 43.78; 440.25, 55.13 and 348.24, 43.77, in ram lambs fed untreated hay, untreated hay supplemented with PKC, treated hay and treated hay supplemented with PKC, respectively. The lambs supplemented with PKC received 91.80 g of DM from PKC. The total DMI of lambs, expressed as g/day or g/kg $W^{0.75}$/day was 422.80, 53.80; 433.00, 55.78; 440.25, 55.13 and 440.00, 55.44 through untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC, respectively. The differences in DMI of ram lambs fed untreated / urea treated hay supplemented with PKC were not significant.

4.5.3 Effect on water intake and urine output

The average water consumption of lambs expressed as L/day or L/kg DMI was 2.39, 5.70; 2.28, 5.35; 2.26, 5.14

Table 12. Effect of urea treatment of Cenchrus hay and/or PKC supplementation on DMI, water consumption and urine output in Nellore Brown weaner ram lambs

	Untreated hay	Untreated hay + PKC	Urea treated hay	Urea treated hay+PKC
Live weight (kg)	15.45 ±1.39	15.25 ±1.05	15.83 ±0.91	15.80 ±1.01
Metabolic body weight (kg)	7.78 ±0.52	7.71 ±0.40	7.93 ±0.34	7.92 ±0.38
DMI through				
Cenchrus hay				
g/day	422.80 ±41.88	341.25 ±43.50	440.25 ±46.45	348.24 ±32.74
g/kg $W^{0.75}$/day	53.80 ±2.84	43.78 ±3.41	55.13 ±3.76	43.77 ±2.30
Palm kernel cake				
g/day	-	91.80 ±0.00	-	91.80 ±0.00
g/kg $W^{0.75}$/day	-	12.00 ±0.59	-	11.67 ±0.54
Total DMI				
g/day	422.80 ±41.88	433.00 ±43.00	440.25 ±46.45	440.00 ±33.00
g/kg $W^{0.75}$/day	53.80 ±2.84	55.78 ±2.85	55.13 ±3.76	55.44 ±2.03
Water intake				
L/day	2.39 ±0.28	2.28 ±0.16	2.26 ±0.18	2.31 ±0.28
L/kg DMI	5.70 ±0.57	5.35 ±0.32	5.14 ±0.93	5.41 ±0.91
Urine output				
L/day	1.04 ±0.14	0.97 ±0.09	0.95 ±0.22	0.92 ±0.30
L/kg $W^{0.75}$/day	0.86 ±0.19	0.84 ±0.15	0.85 ±0.23	0.80 ±0.29

Each value is the average of 4 observations

Values in the rows did not differ significantly ($P > 0.05$)

and 2.31, 5.41 fed rations containing untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC, respectively. The average urine output expressed as L/day or L/kg $W^{0.75}$/day was 1.04, 0.86; 0.97, 0.84; 0.95, 0.85 and 0.92, 0.80 in lambs fed untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC, respectively. It was observed that ammoniation through urea treatment and supplementation with PKC did not show any significant effect on water consumption and urine output of lambs in the present study.

4.5.4 Effect on nutrient digestibility

The effect of urea treatment and/or supplementation of Cenchrus hay with PKC was studied in a metabolism trial and the data on the digestibility of proximate principles and cell-wall constituents of rations are presented in Tables 13 and 14, respectively.

The average DM, OM, CP, EE, CF and NFE digestibilities were 47.98, 52.73, 55.13, 44.08, 51.45 and 55.26% for untreated hay as compared to 51.66, 56.92, 59.90; 56.49, 61.49, 66.92; 59.30, 66.52, 70.78; 49.53, 51.58, 58.98; 55.54, 60.19, 64.43 and 61.59, 65.37, 71.19% observed for rations containing untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC, respectively (Table 13).

Table 13. Effect of urea treatment of Cenchrus hay and / or PKC supplementation on nutrient digestibility (%) of rations in Nellore Brown weaner ram lambs

Nutrient	Untreated hay	Untreated hay + PKC	Urea treated hay	Urea treated hay + PKC
Dry matter	47.98^{a} ± 0.87	51.66^{a} ± 0.91	56.92^{b} ± 1.38	59.90^{b} ± 1.99
Organic matter	52.73^{a} ± 1.18	56.49^{b} ± 1.41	61.49^{c} ± 1.16	66.92^{d} ± 1.76
Crude protein	55.13^{a} ± 1.30	59.30^{b} ± 0.99	66.52^{c} ± 0.70	70.78^{d} ± 1.46
Ether extract	44.08^{a} ± 1.49	49.53^{b} ± 1.09	51.58^{b} ± 0.68	58.98^{c} ± 1.43
Crude fibre	51.45^{a} ± 1.16	55.54^{a} ± 0.52	60.19^{b} ± 0.42	64.43^{c} ± 1.83
Nitrogen free extract	55.26^{a} ± 1.21	61.59^{b} ± 1.59	65.37^{b} ± 2.14	71.19^{c} ± 2.03

Each value is the average of 4 observations

^{abcd}Values in the rows bearing different superscripts differ significantly ($P < 0.01$)

Table 14. Effect of urea treatment of Cenchrus hay and / or PKC supplementation on digestibility (%) of cell-wall constituents in Nellore Brown weaner ram lambs

Nutrient	Untreated hay	Untreated hay + PKC	Urea treated hay	Urea treated hay + PKC
Neutral detergent fibre	$51.93^{a} \pm 0.67$	$53.48^{a} \pm 0.84$	$58.74^{b} \pm 1.07$	$60.62^{b} \pm 1.52$
Acid detergent fibre	$42.78^{a} \pm 1.10$	$44.88^{a} \pm 0.51$	$51.08^{b} \pm 0.84$	$53.48^{b} \pm 1.05$
Hemicellulose	$60.31^{a} \pm 1.22$	$62.80^{a} \pm 1.10$	$67.51^{b} \pm 0.80$	$70.09^{b} \pm 1.03$
Cellulose	$53.52^{a} \pm 1.29$	$56.29^{a} \pm 1.58$	$61.35^{b} \pm 0.91$	$64.22^{b} \pm 1.42$
Lignin	$18.23^{b} \pm 1.26$	$22.70^{c} \pm 1.13$	$12.11^{a} \pm 0.64$	$16.67^{b} \pm 2.25$

Each value is the average of 4 observations

^{abc}Values in the rows bearing different superscripts differ significantly ($P < 0.01$)

The digestibilities of OM, CP, EE and NFE were higher ($P < 0.01$) when untreated hay was supplemented with PKC. Urea treatment has increased ($P < 0.01$) the digestibilities of DM, OM, CP and CF as compared to untreated hay with or without PKC supplementation. The differences in EE and NFE digestibilities were significantly different between untreated and urea treated hays. However, the digestibility differences of EE and NFE were not significant between urea treated hay and untreated hay supplemented with PKC. Supplementation of urea treated hay with PKC significantly increased ($P < 0.01$) the OM, CP, EE, CF and NFE digestibilities as compared to untreated hay with or without PKC supplementation, and urea treated hay. The DM digestibility of urea treated hay supplemented with PKC was significantly higher ($P < 0.01$) from that of feeding untreated hay with or without supplementation but not from urea treated hay.

The average digestibility coefficients of NDF, ADF, hemicellulose, cellulose and lignin were 51.93, 42.78, 60.31, 53.52 and 18.23 for ram lambs fed untreated hay as compared to 53.48, 58.74, 60.62; 44.88, 51.08, 53.48; 62.80, 67.51, 70.09; 56.29, 61.35, 64.22 and 22.70, 12.11, 16.67, respectively for ram lambs fed rations containing untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC (Table 14). Ammoniation through urea treatment has significantly increased ($P < 0.01$) the digestibilities of NDF, ADF, hemicellulose and cellulose. Supplementation of untreated hay with PKC had no significant effect on the digestibilities of cell-wall constituents of rations except for lignin. Supplementation of PKC to urea treated Cenchrus hay, though improved the digestibilities of fibrous cell-wall constituents, the differences in digestibility were not significant. Lignin digestibility was significantly lower ($P < 0.01$) in untreated hay and urea treated hay supplemented with PKC as compared to untreated hay supplemented with PKC.

4.5.5 Nitrogen balance study

Data showing the effect of urea treatment and/or PKC supplementation on N utilization of ram lambs are presented in Table 15. The average N intake from Cenchrus hay expressed as g/day or g/kg $W^{0.75}$/day was 2.63, 0.34; 2.12, 0.27; 9.95, 1.25 and 7.83, 0.98, respectively in lambs fed rations containing untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC. The N intake from PKC in lambs supplemented with PKC, expressed as g/day, or g/kg $W^{0.75}$/day was 2.21, 0.29 and 2.21, 0.28, respectively on untreated and urea treated hay fed rations. The total N intake, expressed as g/day or g/kg $W^{0.75}$/day was 2.63, 0.34; 4.33, 0.56; 9.95, 1.25 and 10.06, 1.27 through untreated hay, untreated hay supplemented with PKC, urea treated hay and

Table 15. Effect of urea treatment of Cenchrus hay and/or PKC supplementation on nitrogen utilization in Nellore Brown weaner ram lambs

Parameter	Untreated hay	Untreated hay + PKC	Urea treated hay	Urea treated hay+PKC
N intake through				
Cenchrus hay				
g/day	2.63[a] ±0.26	2.12[a] ±0.27	9.95[b] ±0.97	7.83[b] ±0.73
g/kg $W^{0.75}$/day	0.34[a] ±0.002	0.27[a] ±0.02	1.25[b] ±0.08	0.98[b] ±0.05
PKC				
g/day	-	2.21 ±0.00	-	2.21 ±0.00
g/kg $W^{0.75}$/day	-	0.29 ±0.01	-	0.28 ±0.01
Total N intake				
g/day	2.63[a] ±0.26	4.33[a] ±0.27	9.95[b] ±0.97	10.06[b] ±0.73
g/kg $W^{0.75}$/day	0.34[a] ±0.02	0.56[b] ±0.01	1.25[c] ±0.08	1.27[c] ±0.05
N excretion (g/day)				
Faeces	1.18[a] ±0.14	1.75[b] ±0.11	3.23[c] ±0.42	3.01[d] ±0.73
Urine	1.72[a] ±0.13	2.14[b] ±0.12	3.67[c] ±0.49	3.21[d] ±0.26
Total	2.90[a] ±0.27	3.89[b] ±0.23	6.90[c] ±0.91	6.22[d] ±0.99
N retention				
g/day	-0.27[a] ±0.04	0.44[b] ±0.08	3.05[c] ±0.12	3.84[d] ±0.25
g/kg $W^{0.75}$/day	-0.035[a] ±0.01	0.057[b] ±0.01	0.38[c] ±0.01	0.49[d] ±0.03
Per cent of intake	-10.26[a] ±1.71	9.90[b] ±1.33	30.93[c] ±2.26	38.32[d] ±1.67

Each value is the average of 4 observations

[abcd]Values in the rows bearing different superscripts differ significantly ($P < 0.01$)

urea treated hay supplemented with PKC, respectively. Supplementation of untreated hay with PKC did not significantly increase the total N intake expressed as g/day but increased ($P < 0.01$) the total N intake per kg metabolic body weight per day. It has been further observed that urea treatment has significantly increased the total N intake (g/day or g/kg $W^{0.75}$/day) of ration. However, supplementation of urea treated hay with PKC did not affect ($P > 0.05$) the total N intake (g/day or g/kg $W^{0.75}$/day) in lambs.

Lambs fed urea treated hay or urea treated hay supplemented with PKC excreted more ($P < 0.01$) N through urine and faeces as compared to lambs fed untreated hay or untreated hay supplemented with PKC. Lambs fed on untreated hay were on negative N balance while those fed untreated hay supplemented with PKC and treated hay with or without PKC supplementation were on positive N balance.

The N retention expressed as g/day or g/kg $W^{0.75}$/day was -0.27, -0.035; 0.44, 0.057; 3.05, 0.38 and 3.84, 0.49, respectively for rations containing untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC. Urea treatment had significantly ($P < 0.01$) increased the N retention of rations with highest N retention in lambs fed urea treated hay supplemented with PKC. The N retention expressed as per cent of intake increased ($P < 0.01$) from -10.26 for untreated hay ration to 9.90, 30.93 and 38.32 for untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC, respectively.

4.5.6 Nutritive value of rations

The DCP, TDN, DE and ME values of untreated/urea treated hay supplemented with PKC are presented in Table 16. The DCP and TDN values were 2.14, 49.16; 3.70, 53.90; 9.35, 57.71 and 10.09, 62.72 for untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC, respectively. Significantly ($P < 0.01$) higher DCP and TDN values were observed for urea treated hay supplemented with PKC followed by urea treated hay, untreated hay supplemented with PKC in comparison to those observed for untreated grass hay.

It was further observed in the present study that urea treatment has narrowed down nutritive ratio from 1:22 for untreated hay to 1:5. The nutritive ratio of untreated and urea treated hay supplemented with PKC were 1:13 and 1:5, respectively. The calculated DE and ME (Mcal/kg DM) values of untreated/urea treated hay supplemented with PKC were 2.17, 1.78; 2.38, 1.95; 2.54, 2.09 and 2.77, 2.27, respectively. Significantly higher ($P < 0.01$) DE and ME values were observed for urea treated hay supplemented with PKC followed by urea treated hay, untreated hay supplemented with PKC as compared to those observed for untreated hay.

Table 16. Effect of urea treatment and / or PKC supplementation on the nutritive value of Cenchrus hay fed to Nellore Brown weaner ram lambs

Parameter	Untreated hay	Untreated hay + PKC	Urea treated hay	Urea treated hay + PKC
Digestible crude protein (%)	$2.14^{a} \pm 0.05$	$3.70^{b} \pm 0.06$	$9.35^{c} \pm 0.10$	$10.09^{d} \pm 0.21$
Total digestible nutrients (%)	$49.16^{a} \pm 1.08$	$53.90^{b} \pm 0.81$	$57.71^{c} \pm 1.05$	$62.72^{d} \pm 1.59$
Nutritive ratio	1:21.97	1:13.57	1:5.17	1:5.22
Digestible energy (DE) Mcal/kg DM	$2.17^{a} \pm 0.05$	$2.38^{b} \pm 0.04$	$2.54^{c} \pm 0.05$	$2.77^{d} \pm 0.07$
Metabolizable energy (ME) Mcal/kg DM	$1.78^{a} \pm 0.04$	$1.95^{b} \pm 0.03$	$2.09^{c} \pm 0.04$	$2.27^{d} \pm 0.06$

DE and ME values were calculated using the factors 4.409 and 3.616 Mcal/kg TDN, respectively (NRC, 1978)

^{abcd}Values in the rows bearing different superscripts differ significantly ($P < 0.01$)

CHAPTER - V

5. DISCUSSION

Anjan (Cenchrus ciliaris) grass, a hardy and vigorously growing dry land and pasture species capable of producing good quality forage is available in plenty in arid and semi-arid areas of the country. The grass is palatable to grazing sheep even at the dead-ripe stage more than any other uncultivated pasture grass.

In the present investigation the effect of urea treatment of Cenchrus hay and / or PKC supplementation on nutrient digestibility and N utilization by Nellore Brown ram lambs was studied.

5.1 CHEMICAL COMPOSITION OF CENCHRUS HAY

Dry matter content of Cenchrus hay used in the present study was 89.34%. On DM basis the CP, EE, CF, NFE and total ash contents of Cenchrus hay were 3.89, 1.38, 31.84, 52.97 and 9.92%, respectively (Table 1). The CP content of Cenchrus hay observed in the present study was lower and the values for CF, NFE and total ash were higher as compared to the values reported by Singh (1975). The EE content of Cenchrus hay used in the present study was higher and that of CP lower as compared to the reported values of Sen *et al.* (1978). However, the values reported for CF, NFE and total ash content were about similar to the values obtained in the present study. The CF content of Cenchrus hay was about similar to that of Bhatia *et al.* (1974).

Fractionation of cell-wall constituents of Cenchrus hay on DM basis revealed 70.98% NDF, 39.45% ADF, 31.53% hemicellulose, 28.91% cellulose, 8.11% lignin and 2.43% silica (Table 1). The ADF and lignin contents were higher by 2.02 and 1.81 percentage units, respectively and hemicellulose lower by 2.99 percentage units, as compared to the values reported by Sen *et al.* (1978). However, values reported for NDF, cellulose and silica were about similar to the values obtained in the present study.

5.2 UREA TREATMENT OF CENCHRUS HAY

Cenchrus hay was initially treated with 30, 40 and 50% moisture levels at a standard urea level of 4% for 10, 15 and 20 days in 2 L capacity plastic jars to hold about 500 g treated material. The effect of varying levels of moisture and incubation periods on the nutritional quality of Cenchrus hay was studied by using data on chemical composition, IVDMD and *in situ* DM disappearance as the criteria of evaluation.

5.2.1 Chemical composition of urea treated Cenchrus hay

The CP content of Cenchrus hay due to urea treatment increased upto a moisture level of 40% with a decrease in CP content beyond 40% moisture level (Table 2). Probably higher solubility of protein due to ammoniation at higher moisture level was responsible for the decrease in CP content observed beyond 40% moisture level. According to Sundstol et al. (1978) approximately one third of added N only bounds during ambient ammoniation of straws and the remaining two third of ammonia is unbound and lost when the materials are aerated. Increase in N content of treated straws with increased moisture content upto a certain level has been confirmed by Solaiman et al. (1979).

In the present study incubation of grass hay for 15 days with 4% urea enhanced the CP content of Cenchrus hay from 3.89 to a maximum level of 14.27% at 40% moisture level. There was a slight decrease in CP content (14.04%) when the urea treated hay with 40% moisture was incubated for 10 days. On an average the CP content of hay increased by 10.15 and 10.38 percentage units due to ammoniation at 40% moisture for 10 and 15 days, respectively. Lowest CP values ranging from 11.43 to 11.71% were observed for hay treated with 50% moisture.

The average values of CP for treated grass hay showed an increase of 225.9% over that of untreated hay. Extending the period of incubation to 10, 15 and 20 days increased the CP content to 230.6, 227.5 and 219.7%, respectively indicating that extending the treatment interval beyond 10 days had no added advantage. This fact was further confirmed by the calculation of per cent incorporation of urea-N to the hay incubated at varying intervals. The average per cent incorporation of urea-N was marginally higher (76) for hay incubated for 10 days in comparison to those treated for 15 (75) or 20 (73) days.

It has been reported that incorporation of urea-N in ammoniated straw is influenced by the ambient temperature (Horton, 1978). Results of Singh (1986) indicated that the increased N by ammoniation exists at various N components and is retained at different places in the straw. About 58% of the ammonia is reported to be irreversibly bound N which is utilized by ruminants depending upon the temperature and pressure at which the ammonia is applied (Lawlor et al., 1981). The temperature of the stored mass increases following addition of ammonia, the amount depending upon the form of ammonia added, moisture content of the material and the size of the mass. Mikami et al. (1986) suggested a moisture level of 30% for straws and 25% for hays for successful ammoniation.

In the present study ammoniation at laboratory scale was carried out during the months of January and February, 1994 having a maximum day temperature ranging from 28.5 to 32.6^{o}C and a minimum temperature ranging from 17.3 to 20.0°C. The relative humidity ranged from 42-87% during the above months. Hence, the maximum period of incubation for ammoniation in the present study was restricted to 20 days keeping in view the prevailing ambient temperature. The conditions existing at the time of urea treatment were in accordance with the recommendations of Sundstol et al. (1978) who stated that a treatment period of less than one week is sufficient when the ambient temperature is more than 30°C. Further, it has been reported that a treatment period of 1 to 4 weeks is sufficient when the amibient temperature is falling between 15 and 30°C.

Mascarenhas-Ferreira et al. (1989) reported decrease in the NDF, hemicellulose and lignin and increase in cellulose content of urea treated Meadow hay. In the present study a decreased trend in NDF was observed irrespective of level of moisture as the period of incubation increased from 10 to 20 days.

5.2.2 Moisture level

Studies on the effect of moisture level on the average CP content of treated hay (Table 3) showed that CP values were higher by 8.64, 10.05 and 7.68 percentage units for hay subjected to 30, 40 and 50% moisture levels, respectively as compared to untreated hay. Increasing the moisture level from 30 to 40% enhanced ($P < 0.01$) the average CP value by 1.41 percentage units. Raising the moisture level from 40 to 50% was however, found to reduce ($P < 0.01$) the CP value by 2.38 percentage units indicating that 40% moisture was adequate for ammoniation of Cenchrus hay through urea treatment. Further it was observed that chemical constituents other than CP were unaffected by the level of moisture when the hay was treated with 4% urea.

Optimum level of moisture is required to dissolve and hydrolyse urea during ammoniation. Several researchers have tried varying moisture levels in an attempt to standardise the technique of urea treatment for several crop residues. Ramana et al. (1990) reported that average CP content of bajra straw decreased as the moisture level increased from 30 to 50%. However, the level of moisture on the chemical composition of bajra straw was not affected markedly beyond 30% moisture level as was observed in the present study at 40% moisture with Cenchrus hay. Shiere and Ibrahim (1989) recommended water levels ranging from 30 to 100 litres/100 kg for different straws to achieve effective ammoniation. Bakshi et al. (1986) observed decline in cellulose and hemicellulose content of urea treated wheat straw with increase in moisture level by 9th day itself. Ammoniation not only improves nutritive value but also serves as an effective method of preservation for wet roughages which is an added advantage to conserve and enrich surplus dry roughage sources for ruminants.

5.2.3 Incubation time

The data indicating the effect of period of incubation on the CP and cell-wall constituents of treated hay (Table 4) revealed that the average CP and cellulose values were higher by 8.97, 2.19; 8.85, 1.81 and 8.55, 1.69 percentage units and the NDF, hemicellulose and permanganate lignin were lower by 1.51, 3.27, 0.63; 2.87, 3.66, 1.10 and 4.24, 4.16, 1.43 percentage units, respectively for hay incubated for 10, 15 and 20 days as compared to untreated hay. A slight decrease in CP and cell-wall constituents was observed as the period of incubation increased from 10 to 20 days.

Since ammonia is a slow reacting chemical, attempts were made to accelerate its action either by increasing the moisture (in temperate regions) or by extending the period of incubation. The ambient temperature while carrying out the present study was higher than the critical level of 30°C throughout. Hence keeping the ambient temperature as constant, effect of urea treatment was compared for 3 treatment periods in the present study. While reviewing the effect of incubation time on the efficacy of ammoniation of cereal straws in temperate zones Sundstol et al. (1978) recommended treatment periods of less than one week when the ambient temperature is more than 30°C. The present study revealed that short incubation intervals are as effective as that of long treatment periods when the ambient temperature is high. For adoption of the technique by the small holders, shorter treatment periods are more practicable due to limited infrastructure facilities available.

As evident from the findings of Mascarenhas-Ferreira (1989) increasing the treatment period reduces the amount of unhydrolysed urea which will be negligible beyond 60 days of storage. Cottyn and de Boever (1988) reported that the materials need optimum exposure to ammoniation to exhibit maximum beneficial effects since ammonia treatment improves the quantity of enzymatic assailable cellulose, because the small NH_3 - molecules are able to penetrate the inter-fibroid spaces of the crystalline cellulose in order to breakdown the H_2bridges.

The findings of the present study showed that minimum period required to enrich the Cenchrus hay through urea treatment is 10 days.

5.2.4 *In vitro* evaluation

The effect of level of moisture and period of incubation on IVDMD of Cenchrus hay (Table 5) revealed that the *in vitro* values were higher by 12.35, 14.91 and 11.37 percentage units for hay subjected to 30, 40 and 50% moisture levels, respectively as compared to untreated hay. Increasing the moisture level from 30 to 40% increased the average IVDMD by 2.56 percentage units. Raising the moisture level further to 50% was, however, found to reduce the IVDMD value indicating that 40% moisture was adequate for effective ammoniation of Cenchrus hay through urea treatment. The average IVDMD values were higher by 0.42 and 0.98 percentage units, respectively by extending the period of incubation from 10 to 15 and 20 days indicating that incubation period of 10 days is adequate for ammoniating Cenchrus hay for effective utilization.

In a similar study Tripathi et al. (1987b) reported higher IVDMD values for rice straw treated with 5% urea solution when incubated in plastic buckets or earthen pits for 4 weeks.

Among the three factors of urea level, moisture gradient and treatment period and their interactions affecting the feeding value of treated straws, moisture gradient and treatment periods as well as their interactions were reported to play a significant role on in vitro DM loss of straw as reported by Yadav and Yadava (1986b). They considered the DM loss during straw treatment as one of the important factors helpful in the selection of optimum time and method of treatment having water involvement.

It has been reported that different straws respond differently to gradients of moisture treatment during ammoniation. Yadav and Yadava (1988) observed significant increase ($P < 0.01$) in IVDMD between moisture gradients in wheat straw but not for the paddy straw. The DM loss during the treatment was reported to occur in a linear manner with minimum loss at 30% moisture level.

Mikami *et al*. (1986) reported differences in response to moisture treatment between straws and hays. The IVDMD of straw was reported to increase proportionately upto 30% moisture level followed by gradual increase upto 40% but the digestibility of hay did not increase beyond 20% level.

In the present study the IVDMD values were significantly higher ($P < 0.01$) at 40% moisture level irrespective of period of incubation. Extending the period of incubation from 10 days to 20 days had no added advantage on IVDMD of Cenchrus hay treated with 4% urea.

5.2.5 *In sacco* evaluation

Samples of Cenchrus hay subjected to 4% urea treatment at varying levels of moisture and periods of incubation were subjected to *in sacco* evaluation using nylon bag technique. The average DM disappearance data of untreated/urea treated hay incubated in the rumen of fistulated rams (Table 6) revealed that as the period of incubation was extended from 12 to 72 h in the rumen, the per cent *in sacco* DM disappearance values of hay progressively increased. Among the treated hay, higher ($P < 0.01$) average DM disappearance values were observed for the hay subjected to 40% moisture irrespective of period of incubation (Table 7). The average in sacco DM disappearance was higher ($P \angle 0.01$) by 7 and 10 per cent with ammoniation at 40% moisture in comparison to 30 and 50% moisture levels, respectively.

The average DM disappearance values at varying periods of ammoniation during urea treatment did not differ significantly irrespective of the time of incubation in the rumen (Table 8). The DM disappearance of treated hay was highest at 72 h incubation.

Since the in sacco DM disappearance values are relevant to the specific periods of incubation in the rumen, effective degradable dry matter (EDDM) values were determined from the in sacco DM disappearance data to determine the optimum level of moisture and period of incubation while ammoniating Cenchrus hay with 4% urea.

Soluble DM fraction 'a' increased from 10 per cent for untreated hay to 19.5 to 20.0 per cent at a moisture level of 40% with incubation periods ranging from 10 to 20 days (Table 9) showing a 100 per cent improvement. The nutritive quality of roughages particularly those containing a high proportion of hemicellulose was reported to respond better with ammoniation (Tohrai et al., 1980). The hemicellulose content of Cenchrus hay used in the present study was 31.53% on DM basis.

It is evident from the present study that the influence of urea treatment in improving the insoluble but degradable fraction 'b' was marginal. Among the different moisture levels compared, higher 'b' values were observed for hay subjected to 40% moisture level irrespective of period of incubation. The overall effect of ammoniation was mediated in the form of 'a', 'b' and 'c' constants of Cenchrus hay and reflected on its EDDM values. The EDDM values increased from 29% for untreated hay to a maximum value of 40% with 40% moisture level at all the incubation intervals indicating that maximum advantage from urea treatment could be achieved by incubating the hay with 4% urea at 40% moisture level for 10 days. Venkataramana *et al*. (1989) earlier reported an improvement in EDDM values by 56 per cent with 4% urea treatment of bajra stalks at 30% moisture level for 20 days indicating that different roughage sources respond differently to ammoniation through urea treatment probably due to changes in the chemical structure of the substrate and the conditions prevailing at the time of treatment.

Based on the chemical, *in vitro* and *in sacco* evaluation studies moisture level of 40% was choosen for ammoniating Cenchrus hay with 4% urea with a minimum incubation period of 10 days.

5.3 *IN VIVO* EVALUATION OF UREA TREATED CENCHRUS HAY

Hay treated with 4% urea at a moisture level of 40% with an incubation period of 10 days was further evaluated in comparison to that of untreated hay with or without PKC supplementation by a digestion-cum-nitrogen balance experiment involving Nellore Brown weaner ram lambs.

For *in vivo* evaluation of hay, urea treatment of Cenchrus hay was carried out in the months of April and May, 1994 when the maximum and minimum temperatures ranged from 37.5 to 39.1°C and 24.9 to 26.2°C, respectively. The relative humidity was with in the range of 34 to 68% during the treatment period for in vivo evaluation. There was not much difference in the average temperatures and relative humidity values prevailing at the time of urea treatment of hay during initial screeing as well as during *in vivo* evaluation study.

5.3.1 Chemical composition of treated hay

Average DM of Cenchrus hay treated with 4% urea at 40% moisture level and incubated for 10 days was 59.7% (Table 10). On DM basis the CP, EE, CF, NFE and total ash values of Cenchrus hay were 14.04, 1.40, 29.97, 44.11 and 10.48%, respectively. The CP content of urea treated hay increased by 3.6-fold as compared to untreated hay. The increase in protein content had reflected in decreased NFE content of treated hay from 52.97 to 44.11%. The total ash content of 4% urea treated Cenchrus hay was higher as compared to untreated hay due to the presence of minerals dissolved in added water.

Determination of cell-wall constituents of treated hay revealed 68.32% NDF, 39.34% ADF, 28.98% hemicellulose, 29.76% cellulose, 6.92% lignin and 2.66% silica on DM basis. The NDF, hemicellulose and lignin fractions of urea treated hay were lowered by 2.66, 2.55 and 1.19 percentage units, respectively as compared to untreated hay.

5.3.2 Chemical composition of palm kernel cake

Proximate analysis of PKC revealed that the DM content of PKC was 91.80%. On DM basis the CP, EE, CF, NFE and total ash of PKC were 15.05, 1.21, 30.35, 44.49 and 8.90%, respectively (Table 11). The CP and EE values of PKC observed in the present study were lower and that of CF higher as compared to the values reported by Devendra (1977). The CP of PKC in the present study was about similar to that of 14.6% reported by Mustaffa Babjee (1988a). However, reported value for EE (4.9%) was higher and CF (16.5%) lower as compared to the values obtained in the present study. The NFE content of PKC used in the present study was higher by 2.77 percentage units and CF lower by 2.85 percentage units as compared to the values reported by Vasanthalakshmi and Krishna (1993). However, values reported for CP, EE and total ash were about similar to the values obtained in the present study.

Fractionation of cell-wall constituents of PKC showed 74.37% NDF, 41.58% ADF, 32.79% hemicellulose, 22.03%

cellulose, 17.41% lignin and 2.14% silica on DM basis (Table 11). For solvent extracted and expeller pressed PKC, Mustaffa Babjee (1988a) reported NDF values of 66.7% and 66.4% and ADF values of 46.1 and 41.8%, respectively. The ADF values of solvent extracted and expeller pressed PKC samples as analysed by different agencies in Malaysia ranged from 40.0 to 46.1% and 39.6 to 44.0%, respectively. The ADF and cellulose values obtained in the present study were higher by 3.03 and 3.64 percentage units and hemicellulose and lignin lower by 2.22 and 3.09 percentage units, respectively in comparison to those reported by Vasanthalakshmi and Krishna (1993). However, the value reported for NDF was about similar to the value obtained in the present study.

5.3.3 Dry matter intake of lambs

The average live weights of lambs were 15.45, 15.25, 15.83 and 15.80 kg and the metabolic body weights were 7.78, 7.71, 7.93 and 7.92 kg fed untreated hay, untreated hay supplemented with 100 g PKC, urea treated hay and urea treated hay supplemented with 100 g PKC, respectively (Table 12). The ram lambs were offered feed to provide DM at 3% of body weight to meet the energy and protein requirements according to Kearl (1982).

The average DMI expressed as g/day or g/kg $W^{0.75}$/day was 422.80, 53.80; 433.00, 55.78; 440.25, 55.13 and 440.00, 55.44; respectively in lambs fed untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC. Urea treatment has increased the total DMI of lambs by 4.13 percentage units when offered as sole roughage source in the ration. Supplementation of untreated/urea treated hay with PKC increased the total DMI of lambs by 2.41, 4.07 percentage units, respectively as compared to untreated hay.

Higher DMI of urea treated roughages could be due to an increased rate of breakdown of the feed particles in the rumen which may induce higher rate of passage of indigestible matter as reported by Oji et al. (1979). Lawlor et al. (1981) reported an increase in DMI of ammoniated wheat straw by 70% with the intake being higher when the treated straws were supplemented with concentrate. However, Venkata Ramana et al. (1989) reported that urea treatment of bajra straw at 4 and 5% levels increased the voluntary DMI by 50 and 70 g/day without any significant effect between treatments on DMI.

In the present study neither urea treatment nor supplementation with PKC had significantly increased the DMI of Cenchrus hay as well as total DMI of the rations. The reason probably could be due to restriction of feed DM to 3% of body weight of lambs. Similarly water intake and urine output did not differ significantly among the different treatments. Agarwal and Rai (1986) had reported that water consumption was unaffected by ammoniation in buffaloes fed wheat straw treated with 4% urea. However, Venkata Ramana (1988) reported that water intake was lower in rams fed urea treated straws which inturn resulted in reduced urine output.

Dry matter intake of sheep depends on the type of diet they are offered. In the present study the DMI of lambs fed untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC were 53.80, 55.78, 55.13 and 55.44 g/kg $W^{0.75}$/day, respectively which were very close to the recommended DM requirement of 55 g/kg $W^{0.75}$/day by Kearl (1982) based on the average of 32 observations.

5.3.4 Nutrient digestibility of rations

Urea treatment (4%) increased ($P < 0.01$) the digestibilities of DM, OM, CP, EE, CF and NFE by 8.94, 8.76, 11.39, 7.50, 8.74 and 10.11 percentage units, respectively as compared to feeding untreated hay alone (Table 13). Supplementation of untreated/urea treated hay with PKC increased ($P < 0.01$) the OM, CP, EE and NFE digestibilities by 3.76, 14.19; 4.17, 15.65; 5.45, 14.90 and 6.33, 15.93 percentage units, respectively as compared to untreated hay.

Supplementation of urea treated hay with PKC increased ($P < 0.01$) the digestibilities of DM and CF by 11.92 and 12.98 percentage units, respectively as compared to untreated hay. Though higher digestibilities were observed for DM and CF by supplementation of untreated hay with PKC, the differences in digestibilities were not significant. PKC is generally considered to be a mediocre energy/protein source for ruminants as evident from the DCP and TDN values of 7.76 and 52.50% as reported by Vasanthalakshmi and Krishna (1994) due to which the impact of supplementation with PKC was not felt much on the digestibility of nutrients in the present study.

Higher digestibility of nutrients from urea treated straws could result from a sustained release of added N into the rumen allowing a more intense microbial fermentation (Dias-Da-Silva and Sundstol, 1986) and increased solubilization of structural constituents (Yadav and Yadava, 1986a). A slower release of bound N was observed by Oji et al. (1979) with ammonia treated straws. It was also possible that ammonium hydroxide production that followed urea hydrolysis in the sealed containers might have led to cleavage of the alkali labile linkages existing between lignin and the structural carbohydrates (Buettner et al., 1982). It was a clear indication that such cleavage increases fibre degradability as was observed in the present study. Results of Wanapat et al. (1985a) revealed that the digestibility coefficients of all the fractions of nutrients were increased by urea ensiling of rice straw.

Protein supplements increase glucose availability either by increasing f... ...ake (ruminal propionic acid production) or by increasing the availability of amino acids (microbial or dietary) for intestinal absorption when they are offered as supplementary to low quality forages (Lindsay, 1970). High quality forage supplements or those which provide critical limiting nutrients enhance rumen ecosystem so as to increase microbial growth, rate of fibre digestion, propionate production and escape of dietary protein.

In the present study ammoniation through urea treatment was found to increase ($P \angle 0.01$) the digestibilities of NDF, ADF, hemicellulose and cellulose by 6.81, 8.30, 7.20 and 7.83 percentage units, respectively (Table 14). The digestibilities of cell-wall constituents except lignin were also increased when untreated / urea treated hay was supplemented with PKC but the differences in digestibility values were not significant. Urea treatment decreased ($P \angle 0.01$) the lignin digestibility by 6.12 percentage units in hay fed lambs while supplementation of untreated hay with PKC increased ($P \angle 0.01$) the lignin digestibility by 4.47 percentage units. Lignin digestibility was found to be lowered ($P > 0.05$) by 1.56 percentage units when urea treated hay was supplemented with PKC.

Increased ($P \angle 0.01$) digestibilities of NDF, ADF and cellulose by 5.8, 4.7 and 5.8 units, respectively were reported by Horton (1981) due to ammoniation in straws. The results of Buettner et al. (1982) with ammoniated Tall Fescue hay revealed higher ($P \angle 0.01$) digestibility coefficients for NDF, ADF, cellulose and hemicellulose, while the lignin digestibility was reduced resulting from the reduction in the lignin percentage associated with ammonia treatment as was observed in the present study with ammoniation through urea treatment. Buettner *et al*. (1982) have further reported that ammoniation had significantly reduced esterbond absorbance and increased amide bond absorbance in the fibre fraction of the hay resulting from the breaking of ester bonds through aminolysis.

5.3.5 Nitrogen utilization in lambs

The total N intake expressed as g/day or g/kg $W^{0.75}$/day was 2.63, 0.34; 4.33, 0.56; 9.95, 1.25 and 10.06, 1.27, respectively in ram lambs fed untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC (Table 15). Urea treatment increased ($P < 0.01$) the total N intake expressed as g/day or g/kg $W^{0.75}$/day by 7.32 and 0.92, respectively as compared to untreated hay. Supplementation of untreated/urea treated hay with PKC increased ($P < 0.01$) the total N intake by 0.22 and 0.93 g/kg $W^{0.75}$/day, respectively as compared to untreated hay. Supplementation of urea treated hay with PKC increased ($P < 0.01$) the total N intake by 7.43 g/day. Though higher N intake was observed through supplementation of untreated hay with PKC, the difference in total N intake expressed as g/day was not significant.

Significantly ($P < 0.01$) higher excretion of N through faeces and urine has reduced the margin of N balance between untreated and urea treated hays supplemented with PKC. It was further observed that ram lambs fed untreated hay were on negative N balance indicating that feeding untreated hay alone could not sustain the maintenance N needs of growing sheep. The N retention expressed as g/day or g/kg $W^{0.75}$/day was higher by 0.71, 0.092; 3.32, 0.415 and 4.11, 0.525, respectively in ram lambs fed rations containing untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC as compared to those fed ration containing untreated hay alone.

Lawlor _et al_. (1981) reported that approximately 58% of the anhydrous ammonia added to the straw was irreversibly bound to the treated material. The N retention studies further revealed that ammoniation of straw has slightly increased N retention of animals. The more conclusive aspect of their study was that when ammoniated straw was fed in conjunction with a concentrate of medium to low CP content it could be possible to maintain a positive N balance. In the present study higher ($P < 0.01$) N retention was observed with urea treated hay supplemented with PKC than with urea treated hay feeding alone due to additional CP contributed by PKC supplementation. Benahmad and Dulphy (1986) stated that urea treatment increased the content of undigestible CP than the digestible CP. As reported by Dias-Da-Silva et al. (1988) more than 90% of the retained N was water soluble when barley straw was treated with anhydrous ammonia. Further they have concluded that the N retained following urea treatment of maize stover represents a source of readily available N for rumen microbes.

The method of urea treatment also appeared to affect the N retention of urea treated straws. The N retained by urea treatment was reported to be 29.9% on stacking and 46.7% on ensiling (Reddy et al., 1988). In the present study urea treatment was attempted in circular concrete tubs ensuring airtight conditions during ammoniation.

5.3.6 Nutritive value of rations

The nutritive value expressed in terms of digestible crude protein (DCP) and total digestible nutrients (TDN) was 2.14, 49.16; 3.70, 53.90; 9.35, 57.71 and 10.09, 62.72%, respectively in ram lambs fed rations containing untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC (Table 16). Urea treatment increased ($P < 0.01$) the DCP and TDN intake by 7.21 and 8.55 percentage units, respectively, as compared to untreated hay.

Supplementation of untreated/urea treated hay with PKC increased ($P < 0.01$) the DCP and TDN intake by 1.56, 4.74 and 7.95 and 13.56 percentage units, respectively, as compared to untreated hay feeding. In an earlier study Rahman et al. (1987) reported the DCP and TDN values as 6 and 48%, respectively for treated wheat straw which were comparable to any maintenance type non-legume forage. In the present study, the respone to urea treatment was higher in comparison to that observed with several straws tested earlier. It appears that hays are more amenable for enrichment through ammoniation in comparison to straws. Venkataramana et al. (1989) reported that ammoniation of bajra stalks increased the DCP and TDN intake in rams fed 4 or 5% urea treated bajra stalk rations. Venkataramana (1988) reported that urea treatment had narrowed down the nutritive ratio from 1:7.4 to 1:4.1. In the present study it was observed that the nutritive ratio was narrowed down from 1:22 to 1:5 due to 4% urea treatment of Cenchrus hay in lambs. Supplementation of untreated/urea treated hay with PKC narrowed down the nutritive ratio to 1:14 and 1:5, respectively as compared to a wide nutritive ratio of 1:22 observed with the untreated hay feeding in sheep.

The calculated DE and ME values expressed in terms of Mcal/kg DM were higher ($P < 0.01$) by 9.68, 9.55; 17.05, 17.42 and 27.65, 27.52, respectively, in ram lambs fed rations containing untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC as compared to those fed untreated hay (Table 16). Puri and Gupta (1990) has earlier reported that feeding of urea treated rice straw increased the ME intake in cross-bred calves. Similarly, Venkataramana et al. (1989) reported higher DE and ME intakes in rams fed ration containing urea treated bajra stalks as compared to those fed untreated straw.

In the present study the daily intake of DCP worked out to be 9.05, 16.02, 41.42 and 44.40 g and TDN 207.95, 233.39, 255.66 and 275.97 g for rations containing untreated hay, untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC, respectively. Ram lambs fed urea treated hay with or without PKC supplementation were on positive N balance. It was evident that feeding of Cenchrus hay with or without PKC supplementation could not meet the DCP and TDN requirements of growing lambs. However, feeding of urea treated Cenchrus hay supplemented with PKC could meet the DCP (ICAR, 1985) and TDN (Kearl, 1982) requirements of growing lambs.

5.4 CONCLUSIONS

Based on the results of the present investigation the following conclusions are drawn.

1. Cenchrus ciliaris grass hay appeared to be a potential roughage source to be enriched by ammoniation through urea treatment.

2. Optimum conditions for ammoniating Cenchrus hay through 4% urea treatment were found to be 40% moisture and 10 days of incubation with a 3.6 fold increase in crude protein and 37% improvement in rumen degradability of dry matter.

3. Urea treatment significantly increased the nutrient digestibility, nitrogen utilization and nutritive value of Cenchrus hay in Nellore Brown weaner ram lambs.

4. Urea treated Cenchrus hay supplemented with 100 g PKC could meet the protein and energy requirements of growing Nellore Brown weaner ram lambs under intensive feeding.

CHAPTER - VI

6. SUMMARY

Cenchrus ciliaris, a hardy and vigorously growing perennial dry land and pasture species of grass is available in plenty in arid and semi-arid areas of the country to be fed either in green form or as a hay. However, hay prepared from matured grass could not sustain the nutrient requirements of growing livestock. To improve the nutritive value of poor quality roughages such as cereal straws, ammoniation through urea treatment is being extensively practiced. During the recent past cereal straws have received maximum attention for enrichment through urea treatment in the country. No attempts have been made to improve the nutritional quality of grass hays through urea treatment.

In the present study an attempt has been made to standardise the urea-ammoniation technique to exploit the potential feeding value of Cenchrus ciliaris grass hay for growing sheep using chemical composition, _in vitro_ and _in sacco_ evaluation techniques as criteria of evaluation followed by detailed _in vivo_ evaluation studies.

On DM basis the Cenchrus hay contained 3.89% CP, 70.98% NDF, 39.45% ADF, 31.43% hemicellulose, 28.91%

cellulose, 8.11% lignin and 2.43% silica, respectively. Ammoniation was attempted through 4% urea at varying moisture levels of 30, 40 and 50% and incubated for 10, 15 and 20 days. Pilot studies were carried out in the laboratory by incubating 500 g of chopped 4% urea treated Cenchrus hay in 2 L capacity screw capped plastic containers.

Among the several chemical constituents considered, the CP content increased by 3.6-fold during urea treatment. The CP content increased ($P < 0.01$) by raising the moisture level from 30 to 40%. Extending the period of incubation from 10 to 20 days did not affect the CP content of treated hay. Highest CP of 14.27% was observed by extending the period of incubation of 40% moisturised hay to 15 days. The effect of moisture level and period of incubation on the composition of cell-wall constituents of Cenchrus hay was negligible.

The IVDMD value was 43.10% and higher for urea treated hay incubated for 20 days at 40% moisture as compared to 27.68% for untreated hay with sheep rumen liquor. The average IVDMD value increased ($P < 0.01$) from 40.03 to 42.50% by increasing the moisture level from 30 to 40% irrespective of period of incubation.

The treated hay was further evaluated by using _in sacco_ DM disappearance data obtained from nylon bag technique. Higher ($P < 0.01$) average _in sacco_ DM disappearance value of 52.13% was observed for hay subjected to 40% moisture level as compared to 48.76 and 47.80%, respectively with 30 and 50% moisture levels without any added advantage by extending the period of incubation beyond 10 days.

The constants 'a' (readily soluble), 'b' (insoluble but degradable) and 'c' (rate constant/h) were derived by fitting a curve by eye to the data points of *in situ* DM disappearance values. An outflow rate (k) of 0.05/h was used to calculate the effective degradable dry matter (EDDM) and to compare the effect of treatment conditions on the rumen degradability of Cenchrus hay. The soluble DM fraction (20%) and insoluble but degradable DM fraction (46.5%) were higher for hay incubated for 20 days at 40% moisture in comparison to other treatment combinations. Lower 'a' and 'b' constants of 16.5 and 43.5% were observed for hay incubated for 15 days at 50% moisture level. The EDDM value was higher (40.32%) for 4% urea treated hay incubated for 20 days with 40% moisture while the value was lower (35.34%) when ammoniation was attempted at 50% moisture with an incubation period of 15 days. However, the differences were negligible among the values calculated for hays incubated for 10, 15 or 20 days at 40% moisture.

Based on the chemical, *in vitro* and *in sacco* evaluation studies moisture level of 40% and incubation period of 10 days were choosen as the optimum conditions for ammoniation of Cenchrus hay through 4% urea treatment for *in vivo* evaluation. The effect of feeding 4% urea treated hay with or without Palm kernel cake (PKC) supplementation on the performance of Nellore Brown weaner ram lambs was studied in a digestion-cum-nitrogen balance experiment involving 4 Nellore Brown weaner ram lambs in a 4 x 4 latin square design. The lambs were fed untreated hay, untreated hay supplemented with PKC (100 g), urea treated hay or urea treated hay supplemented with PKC (100 g) at 3% of their body weight to meet the energy and protein requirements. On DM basis PKC choosen for the present study had 15.05% CP, 74.37% NDF, 41.58% ADF, 32.79% hemicellulose, 22.03% cellulose, 17.41% lignin and 2.14% silica.

Urea treatment increased the DMI of ram lambs from 53.80 to 55.13 g/kg $W^{0.75}$/day. Supplementation of untreated/urea treated hay with PKC increased the DMI of rations from 53.80 to 55.78 and 55.44 g/kg $W^{0.75}$/day, respectively. However, neither urea treatment nor supplementation with PKC could increase the DMI of Cenchrus hay or total ration. Further the daily average water consumption and urine output were unaffected by urea treatment.

Urea treatment increased ($P < 0.01$) the digestibilities of DM, OM, CP, EE, CF and NFE by 8.94, 8.76, 11.39, 7.50, 8.74 and 10.11 and that of NDF, ADF, hemicellulose and cellulose by 6.81, 8.30, 7.20 and 7.83 percentage units, respectively. Supplementation of PKC to untreated/urea treated hay increased ($P < 0.01$) the OM, CP, EE and NFE digestibilities by 3.76, 14.19; 4.17, 15.65; 5.45, 14.90 and 6.33, 15.93 percentage units, respectively. It was further observed that supplementation of urea treated hay with PKC increased ($P < 0.01$) the digestibilities of DM and cellulose by 11.92 and 12.98 percentage units, respectively. The digestibilities of cell-wall constituents with the exception of lignin were also increased when untreated ($P > 0.05$) / urea treated ($P < 0.01$) hay were supplemented with PKC.

The N balance study revealed that urea treatment increased ($P < 0.01$) the average total N intake expressed as g/day or g/kg $W^{0.75}$/day by 7.32 and 0.92, respectively. Supplementation of untreated/urea treated hay with PKC increased ($P < 0.01$) the total N intake expressed as g/kg $W^{0.75}$/day by 0.22 and 0.93, respectively. The N excretion of lambs through faeces and urine was higher ($P < 0.01$) due to urea treatment of hay or PKC supplementation. It was further observed that ram lambs fed untreated hay ration were on negative N balance indicating that untreated hay feeding could not meet the maintenance requirements of growing sheep. The N retention expressed as g/day or g/kg $W^{0.75}$/day was higher by 0.71, 0.092; 3.32, 0.415 and 4.11, 0.525, respectively in ram lambs fed rations untreated hay supplemented with PKC, urea treated hay and urea treated hay supplemented with PKC as compared to those fed untreated hay alone.

The nutritive value of Cenchrus hay expressed as DCP and TDN was 2.14 and 49.16%, respectively. Urea treatment increased ($P < 0.01$) the DCP and TDN values of Cenchrus hay by 7.21 and 8.55 percentage units, respectively. Supplementation of PKC to untreated / urea treated hay increased ($P < 0.01$) the DCP and TDN values by 1.56, 4.74 and 7.95 and 13.56 percentage units, respectively as compared to untreated hay feeding alone.

The results of the present study revealed that Cenchrus ciliaris hay appeared to be a potential roughage source for sheep when ammoniated through 4% urea treatment. Optimum conditions for ammoniating Cenchrus hay through 4% urea treatment were found to be 40% moisture and 10 days of incubation. Neither untreated hay supplemented with PKC nor urea treated hay could meet the recommended DCP and TDN requirements of growing sheep. However, urea treated hay supplemented with 100 g PKC could meet the protein and energy requirements of Nellore Brown weaner ram lambs.

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