UTILIZATION OF COTTON STRAW AS RUMINANT FEED USING DIFFERENT PROCESSING TECHNIQUES

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CERTIFICATE

Shri G.V. Narasa Reddy has satisfactorily prosecuted the course of research and that the thesis entitled "Utilisation of cotton straw as ruminant feed using different processing techniques" 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: 28/3/84

(M. RAJ REDDY)
Major Adviser

CERTIFICATE

This is to certify that the thesis entitled "Utilization of cotton straw as ruminant feed using different processing techniques" submitted in partial fulfilment of the requirements for the degree of "Doctor of Philosophy" in Veterinary Science of the Andhra Pradesh Agricultural University, Hyderabad is a record of the bonafide research work carried out by Sri G.V. Narasa 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 or has been published. Published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

(M. RAJ REDDY)
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(G.V. NARASA REDDY)

ABSTRACT

Non-cereal based, two low cost ready-made complete rations, using untreated/NH_3-treated ground whole cotton plants (GWCP) as sole source of roughage (45%) were formulated and processed into mash and pellet forms. The GWCP was treated with anhydrous ammonia (NH_3) at 3.5 per cent level on dry matter basis at room temperature in polythene bags and preserved for 42 days. The rations containing untreated GWCP were made isonitrogenous as that of treated rations by supplementing with 1.5 per cent urea. The resulting four experimental rations were (1) Complete feed (mash) with untreated GWCP; (2) Complete feed (pellet) with untreated GWCP; (3) Complete feed (mash) with NH_3-treated GWCP and (4) Complete feed (pellet) with NH_3-treated GWCP.

Four metabolic trials involving 4 permanently fistulated male Murrah buffaloes in a 4 X 4 latin square, a 90-day growth trial involving 24 cross-bred male calves (6 in each group) and a metabolic trial involving 12 cross-bred male calves (3 from each group of growth trial) were conducted to assess the nutrient utilization, growth rate, feed efficiency and the rumen fermentation patterns. Nitrogen constituents, total volatile fatty acids and pH values were determined on strained rumen liquor of buffaloes taken before feeding (0 hours) and at 2, 4 and 6 hours post-feeding.

Ammoniation increased the crude protein content of GWCP from 7.8 to 16.0 per cent. Voluntary intake of dry matter,

organic matter and gross energy were improved by ammoniation and their digestibilities were improved by ammoniation as well as pelletization in both species. However, a decreased trend in crude protein digestibility was observed with NH_3-treated GNCP. Nitrogen-free extract digestibility was improved by ammoniation and pelleting in buffaloes as well as in calves. Digestibilities of crude fibre and all the Van Soest components were improved by ammoniation but not by pelletization in both the species except for hemicellulose in buffaloes. All the animals were on positive nitrogen, calcium and phosphorus balances. Buffaloes showed higher utilization of nutrients than calves on all the rations.

Higher average daily gain was observed in calves fed on rations containing NH_3-treated GNCP. Pelleting improved average daily gain only on ration containing untreated GNCP. Feed efficiency was improved both by ammoniation and pelletization. Ammoniation of GNCP increased the cost of feed per kg weight gain. The concentrations of total nitrogen, TCA-insoluble nitrogen, residual nitrogen and food and protozoal nitrogen increased with ammoniation and pelletization whereas a reverse trend was observed for ammonia nitrogen. Both ammoniation and pelletization decreased the pH values of strained rumen liquor with a corresponding increase in total volatile fatty acids concentrations. The concentrations of all nitrogen fractions and total volatile fatty acids were highest at 2 hours

post-feeding and then declined slowly except for residual nitrogen which showed peak at 4 hours post-feeding. pH was lowest at 2 hours post-feeding and increased slowly thereafter. These results suggest that the nutritive value of GNCP can be improved by NH_3-treatment rather than urea and further improvement by pelletization.

CHAPTER I

Introduction

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INTRODUCTION

As per estimates of National Commission on Agriculture, NCA (1976), only 2/3 of the fodder and 1/4 of concentrate required for providing adequate nutrition to the present livestock population are produced in the country. It has been estimated (FAO, 1979) that livestock production should increase by 4.7 per cent annually between 1980 and 2000 to meet the needs of the human population. Adequate feed resources to accomplish this increase will depend upon the proper use of forage (grazed and preserved) and of crop and agro-industrial by-products, plus greater use of feed grains and concentrates. In many areas feed management systems should be developed to control misusage and proper use of range and other feed resources and to maximize the utilization of forage available to small farmer, who own maximum number of cattle and buffaloes which will have great impact on the rural economy of the weaker sections of the society.

The main drawbacks with poor quality dry fodders which comes in the way of utilization by ruminants are low voluntary consumption and poor utilization. The energy content of these materials is poorly utilized by the microbial population in the rumen due to the presence of lignocellulose, whose components are either indigestible (lignin) or act as a barrier between the potentially digestible fraction (cellulose and hemicellulose) and the digesting enzymes.

However, the intake and digestibility of crop residues may be increased by physical and chemical treatments. The nutrient intake of low quality roughages may be increased by reducing particle size and increasing density as in pelleting and chemical treatments including the use of alkalies like anhydrous ammonia and sodium hydroxide. The advantage of using NH_3 in comparison with NaOH is mainly that the increase in the microbial requirement of nitrogen when the potential digestibility is increased is supplied by NH_3 which is absorbed by the straw. Another practical advantage is that no mechanical processing of the straw is required before treatment. Further, an excess of ammonia in the urine may be a useful nitrogen fertilizer whereas an excess Na may, in the long-term proved harmful to soil structure. Moreover, anhydrous ammonia has been shown to improve the nutritive value of low quality forages such as corn stover, wheat straw, grass hay etc., by several workers all over the world.

The concept of complete diet systems have been introduced in recent years in most of the developed countries with the aim of simplifying the feeding high yielding dairy cows so that labour is saved whilst maintaining tighter control of cows nutrition and also facilitate the use of least-cost methods of formulation. However, the complete diet concept could be exploited in most of the developing and under-developed countries, where there is severe shortage of feed stuffs, in-order to utilize locally available crop residues, agro-industrial

by-products and wastes for developing low-cost ready-made balanced feeds which would be of immense use in successful implementation of livestock development programmes among the marginal and small farmers, landless labour and other weaker section of the society and also helps in augumenting feed resources for efficient utilization nutrients for maximising livestock production.

Andhra Pradesh State is growing cotton in a vast area (4,36,500 ha). The whole cotton plant after the last picking of cotton will be thrown either as waste or used as firewood in some villages. Due to introduction of new hybrid varieties which are grown in black cotton soils and are being irrigated, such varieties even after last picking of cotton would contain about 25-30 per cent of leafy material. About one lakh tonnes of dry matter is estimated to be produced every year from these waste cotton plants.

In this study, an attempt was made to utilize dry whole cotton plants after the last picking of cotton as sole source of roughage in the complete feeds for ruminants by applying different processing techniques like anhydrous ammonia treatment, grinding and pelleting. The following observations were recorded: Effect of anhydrous ammonia treatment on ground whole cotton plant on voluntary intake digestibility and nutrient utilisation in Murrah buffaloes and growing cross-bred calves. The effect of feeding these rations on growth rate

and feed efficiency among cross-bred calves and cost of processing and the cost of complete feeds were also assessed. The rumen fermentation studies were also undertaken to find-out the pattern of various nitrogen fractions, pH and total volatile fatty acids in the rumen liquor at different periods after feeding in buffaloes.

CHAPTER II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

2.1 UTILIZATION OF COTTON PLANT BY PRODUCTS AS ROUGHAGE SOURCE IN RUMINANTS

Agro-industrial by-products and crop residues form a potential source of energy for livestock. Dried cotton plants after last picking of the cotton and the by-product from cotton ginning industry can be used as roughage source in ruminants.

Erwin and Roubicek (1958) found that cotton gin trash when fed as part of roughage, was equal to silage in the production of steer gains and that the silage-gin trash, grain mixture produced desirable gain in steers.

Arndt et al. (1980) treated cotton plant by-product (CPP) with 4 per cent NaOH and fed at 70 per cent of the total dietary intake to growing lambs and a rumen fistulated steer. Sodium hydroxide treatment decreased organic matter, cellulose and lignin content of CPP and increased ash content. Digestibility of dry matter, organic matter and cell walls were increased but had no effect on calcium and phosphorus balances.

Ben-Ghedalia and Shefet (1980) ground cotton straw and treated with 46 per cent NaOH 8g, NaOH/100 g dry straw, for 60 days anaerobically or was untreated or treated with NaOH, placed in a glass column and had ozone gas passed through it for 1 hour. Ozone treatment increased cell contents but decreased the proportions of ADF, cellulose and lignin; NaOH

had opposite effects. Hemicellulose in the original untreated straw, 11.5 per cent of organic matter was decreased to 2.8 per cent by NaOH, to 8.4 per cent by ozone and to 4.9 per cent by NaOH and ozone. Digestibility of organic matter was 33, 42, 58 and 66 per cent respectively.

Latter, Ben-Ghedalia et al. (1981) reported that NH_4OH did not affect the lignin content but ozone decreased lignin and hemicellulose, and increased cell contents by 50 per cent. The pH of cotton straw was reduced from 6.11 to 2.28 by ozone, probably due to the formation of organic acids derived from the oxidized lignin. Ultraviolet absorbing substances, including phenolic components were apparently released. Organic matter digestibility was decreased by more than 100 per cent by the ozone treatments as a result of the partial conversion of cell walls into cell contents and the increased degradation of cell wall.

Arndt and Richardson (1982) indicated that dry matter digestibility of NaOH treated cotton plant by-product was increased by monensin, that NaOH treated CBP was equal to corn silage and superior to cotton seed hulls for growing - finishing lambs and that NaOH treated CBP was superior to untreated CBP for growing feedlot steers.

2.2 EFFECT OF AMMONIA TREATMENT OF LOW QUALITY ROUGHAGES ON COMPOSITION, GROWTH AND NUTRIENT UTILIZATION

Anhydrous ammonia treatment of poor quality roughages has been shown to produce the most promising results by

improving their crude protein content and nutritive value.

Huber and Santana (1972) compared the feeding value of corn silage treated with an ammonia solution at ensiling with that of urea-treated and control silages in dairy cattle rations. Of all silage rations with no protein supplement, heifers ate more of the ammoniated than the control silage indicating a superior protein nutrition. Lactating cows showed higher milk yield fed ammonia and urea-treated silages than for negative control rations with no added nitrogen. No significant differences in production were noted for cows fed control, urea-treated or ammonia-treated silages at equal dietary nitrogen.

The experiments conducted by Waiss et al. (1972) indicated that optimal processing conditions were to treat rice straw with 5 per cent of added ammonia (by weight) and 30 per cent of water (by weight) for about 30 days in ambient temperature. Under these conditions, enzymatic digestibility was increased by 10 per cent and nitrogen content by 133 per cent. 'In vivo' digestibility trials also showed enhanced digestibility of treated straw.

Garrett et al. (1974) described improved feed intake, daily gain and cellulose digestibility by ammonia treatment of rice straw in comparative slaughter, feeding and digestion trials with lambs. Further, ammonia treatment improved lamb

gains by 35 per cent which was mainly due to improved cellulose digestibility and an increase in feed consumption.

Rounds and Klopfenstein (1974) showed improved '*in vitro*' dry matter digestibility of corn cobs with NH_4OH treatment. Combining NH_4OH treated cobs with corn silage promoted daily gain and feed efficiency in lambs equal to corn silage.

Knapp *et al.* (1975) observed increased IVDMD and IVCWD of fescue hay by NH_3 treatment. They felt that cattle will readily consume ammoniated hay without adverse effects and that digestibility of highly lignified materials such as corn stalks, corn cobs or straw might be significantly increased by NH_3 treatment.

Garrett *et al.* (1976) reported that NH_3 treatment of rice straw fed at 72 and 36 per cent to lambs improved feed intakes and daily gains compared to untreated straw.

Al-Rabbat and Heaney (1978) stated that anhydrous ammonia treatment of wheat straw increased the digestibilities of energy, nitrogen, ADF and cellulose in mature wethers. Performance of lambs in a growth trial indicated that the NH_3 treated straw ration contained considerable productive energy resulting in 86 per cent higher gains and 59 per cent higher feed efficiency than on the untreated straw ration.

Treatment with ammonia (3% based on the dry weight of the substrate) gave considerable improvement in the '*in vitro*'

organic matter digestibility of Jerusalem artichoke tops collected at tuber harvest stage, sorghum grain crop residue, wheat chaff and poor quality grass hay. All the material showed large increases (about 2 to 4 fold) in nitrogen content after NH_3 treatment (Coxworth et al., 1978).

Morton (1978) with growing Hereford steers found higher intakes of NH_3 treated wheat, barley and oat straws. Apparent digestibilities of dry matter and crude fibre were higher in ammoniated wheat and oat straw than the corresponding untreated straws. Neither straw intake nor dry matter digestibility were improved by ammoniation when supplements were fed though crude fibre digestibility was increased in wheat and oat straw rations.

Kernan and Coxworth (1978) described a practical method of treating straw with anhydrous ammonia on an 'on-farm' scale. They reported typical improvements in Neepawa wheat straw from 3 to 8 per cent crude protein and from 33 to 44 per cent digestible organic matter and this provided a maintenance ration for wintering pregnant cows.

Tohria et al. (1978) observed increase in CP content and decrease in NDF content of rice straw and rice husk by anhydrous ammonia treatment with increasing ammonia upto 5 or 10 per cent and with duration of treatment for 15, 30 or 60 days. Other components were not affected.

Garrett et al. (1979) conducted comparative slaughter feeding trials (sheep and cattle) with concurrent digestion experiments (lambs) to determine the value of alkali treated (NaOH or NH_3) rice straw in diets at 72 and 36 per cent. They observed similar general pattern of response for lambs and steers. The diets containing 72 per cent treated rice straw were consumed larger quantities and less feed was required per unit of gain when compared to results with untreated straw diets. The treated straw diets also had higher net energy values. Digestibility of organic matter, cell walls and energy was higher for most 72 per cent treated rice straw diets. Nitrogen digestibility was lower for those diets containing the treated straw at 72 per cent level. NH_3 treatment approximately doubled the nitrogen content of the straws but the availability of this added nitrogen was not known.

Horton and Steacy (1979) observed increased digestibilities of dry matter, organic matter, crude fibre and gross energy of rations containing ammonia treated cereal straws (barley, oat and wheat) than those containing the corresponding untreated straws in steers.

Solaiman et al. (1979) studied the effect of NH_4OH treatment of wheat straw with different moisture levels (10 to 15%), stored at room temperature, for different periods (1 to 60 days). Days post-treatment and water level had significant linear effects on both IVDMD and total

nitrogen content. NH_4OH treatment decreased straw hemicellulose and NDF fractions and increased digestibility of NDF, ADF and cellulose fractions.

Lowlor and O'Shea (1979) fed untreated or ammonia treated (3% anhydrous ammonia for 30 and 56 days) wheat straw to appetite with supplement of barley or a concentrate mixture with 16 per cent crude protein to 12 wether lambs. Digestibility of '*in vitro*' dry matter was 15 and '*in vivo*' was 14.2 per cent units greater with ammoniated than with untreated straw. With ammoniation the crude protein in the straw increased from 3.1 to 7.6 per cent. Intake by lambs was 70 per cent greater for ammoniated than for untreated straw.

Morris and Mowat (1980) studied the effect of ammoniation and grinding of corn stover in steers adding urea to untreated rations. Ammoniation and grinding increased the digestibility of dry matter and energy. Ammoniation increased the digestibility of DM, OM and NDF whereas grinding decreased the digestibility of DM, OM and NDF compared to chopping.

Tohria *et al.* (1980) inferred that the nutritive quality of roughages, in particular those containing a high proportion of hemicellulose, may be considerably improved by treatment with ammonia.

Bermuda grass hay untreated and treated with anhydrous ammonia to increase crude protein from 8.83 to 15.88 was

given to appetite for 42 days to 2 groups of 8 heifers 2 years old and weighing 775 lb. Daily gains were 0.56 and 0.75 lb for similar daily intake. Digestibility of dry matter of untreated and treated hay was 55.8 and 61·2 per cent '*in vivo*' and 64.6 and 64.4 per cent '*in vitro*' (Utley *et al.*, 1980).

Zafren (1980) reported that treatment of straw with ammonia increases its digestibility, feed value and crude protein content. Ammonia reacts with acetyl groups of straw to form ammonium acetate which is considered better than urea, and could replace upto 35 per cent of protein in diets for cattle, sheep and goats.

Horton (1981) fed a concentrate and NH_3 treated straw (oat, barley or wheat) to steers at 1 per cent of body weight for the measurement of apparent digestibility. Hemicellulose and lignin contents tended to be lower but cellulose was not affected by NH_3 treatment. Further, the pooled data showed that ammoniation increased the digestibility of NDF, ADF and cellulose in the diets by 5.8, 4.7 and 5.8 percentage units, respectively. Improvements were largest for wheat straw diets averaging about 17 per cent and were similar for oat and barley straw diets at about 8 per cent.

Maingi *et al.* (1981) undertaken a study to investigate the effectiveness of anhydrous NH_3, aqueous NH_4OH and urea

+ urease as sources of ammonia for treating maize stover, maize and wheat straws at graded treatment rates of 0, 25 and 50 g NH_3/kg DM of roughage and at 2 moisture levels of 20 and 40 per cent and allowed to react for 15 or 30 days. Rate of ammonia but not the moisture level or days of reaction was the most important factor in enhancing IVDMD, IVOMD and CP. While anhydrous NH_3 was most effective in improving NH_4OH had a similar effect in increasing IVDMD and IVOMD of rice and wheat straws and urea + urease was the least effective but promising.

Peterson et al. (1981) observed higher DMD, DM intake and cell wall digestibility with 3 per cent NH_3 treated than untreated corn stalks in lambs. Further, they also observed more feed intake and weight gain in steers fed 3 per cent NH_3 treated than untreated corn cobs.

Borhami and Sundstol (1982) reported that both anhydrous and aqueous ammonia improved the IVDMD, IVOMD and ESOM (Enzyme soluble organic matter) of the straw as compared with the untreated samples. However, aqueous NH_3 caused significantly higher improvements than did anhydrous NH_3.

Borhami et al. (1982) concluded that spraying NH_3 treated straw with organic acids effectively reduced the loss of ammonia and increased the nitrogen content of the straw. Another advantage of this was that the air pollution with

ammonia which may occur in the barn when the straw was not well aired was effectively prevented. Spraying with organic acids had no negative effect on the digestibility of the straw. The nitrogen supply and the digestibility of nitrogen in the animal seemed to be markedly improved.

Buettner et al. (1982) observed ammoniation of tall fescue hay at 30 g/kg increased voluntary intake and dry matter, cellulose and hemicellulose digestion coefficients in lambs and cattle. Infrared spectral characteristics of the treated and untreated hays indicated that ammoniation significantly reduced ester bond absorbance in the fibre fraction of the hay. These changes presumably resulted from the breaking of ester bonds through ammonolysis. The breaking of ester bonds between lignin and structural carbohydrates may have been primarily responsible for the greater fibre digestibility of the ammoniated hay.

Ammoniation of corn cobs and husks increased the dry matter intake and digestibility of most cell wall fractions in lambs (Cook et al., 1982).

Ammonia treatment of wheat straw improved the intake by 30 per cent and digestibility by 20 per cent (from 42 to 62%) compared with untreated straw in wethers. This also showed very satisfactory weight gains for diets based on treated straw with 30 per cent concentrates as barley/urea

or soyabean meal and average feed intake increased throughout the period in performance trial with cross-bred lambs(Cordesse, 1982a). Sheep ate 28 to 53 per cent more than the untreated straw. Treatment increased DM and organic matter digestibility by 10 to 13 per cent units. Nitrogen digestibility, initially zero, increased to 25 to 45 per cent (Cordesse, 1982b).

Herrera - Saldana et al. (1982) suggested that treatment of wheat straw with NH_3 will improve its nutritive value, but supplementary energy may be required for maximum utilization of added nitrogen. Ammoniation increased the intake of DM, OM, CP and GE and apparent digestibilities of CP, ADF and GE in steers.

Horton et al. (1982) demonstrated in steers that both ammonia treatment and pelleting of shredded wheat straw improved gains and feed efficiency by the same amount. Alkali treatment followed by pelleting was less effective. There was no interaction between ammoniation and either pelleting or alkali treatment. Pelleting had no effect on organic matter digestibility but decreased NDF and cellulose digestibility. Organic matter and NDF digestibility increased following chemical treatment. Intake, gain and feed efficiency were improved by 11, 34 and 17 per cent by pelleting and 12, 36 and 17 per cent by ammoniation, respectively.

Ammoniation of wheat straw increased ADG, DM intake and gain/feed in growing steers (Nelson et al., 1982).

Saenger et al. (1982a) reported that apparent digestibility of NDF, ADF, hemicellulose and cellulose was increased by NH_3 treatment of corn stalks than untreated without supplement or with supplement of urea or soyabean meal. Apparent nitrogen digestibility was less than for rations supplemented with urea or soyabean meal. Ammoniation increased the crude protein content, IVDMD and dry matter intake in beef heifers of wheat straw and soyabean residue (Saenger et al., 1982b).

Saenger et al. (1982c) studied the effect of ammonia treatment of corn stover on digestibility, intake and performance of beef cattle. The diet containing NH_3 treated corn stover had a higher dry matter digestibility, crude protein content and dry matter intake than the rations with control stover, supplemented with soyabean meal or urea. Weight changes by steers fed all the diets were not different.

Increase in IVDMD and decrease in lignin and hemicellulose contents of wheat straw were observed by Streeter and Horn (1982) by NH_3 and then with peracetic acid treatment. Cellulose content was not affected by the action of peracetic acid or ammonia.

Gordon and Chesson (1983) determined by the nylon bag technique in sheep that loss of nitrogen on prolonged storage after ammonia treatment of barley straw did not affect its digestibility of dry matter or cellulose.

Horn et al. (1983) indicated that increasing the water content of straw will increase ammonia retention and the effectiveness of ammoniation. For residues such as wheat straw, which have hard cuticular surface, disruption of the cuticular surface would appear to be a means of increasing penetration of water and perhaps exposing a greater number of binding sites for ammonia.

Ammonia treated barley straw showed higher dry matter digestibility, daily feed intake and daily live weight change than untreated straw supplemented with urea. Anhydrous or aqueous ammonia and isonitrogenous amounts of urea were injected into large round bags containing whole crop barley or oats collected with a forage harvester. The digestibility of starch by steers was about 92 per cent for ammonia treated samples and 78 per cent for urea treated samples (Orskov et al., 1983).

2.3 EFFECT OF COMPLETE PELLETED FEEDS ON GROWTH RATE AND NUTRIENT DIGESTIBILITY

The use of complete ration is an efficient method of controlling the ratios of the various feed ingredients and nutrients. Likewise it is a valuable method of administering minute amounts of ingredients, or ingredients that may not be palatable.

Cate et al. (1954) observed an increase in average daily gain and feed consumption when they fed pelleted feed to lambs containing timothy meal as the roughage. They observed economy in feed utilization and greatest rapidity of finishing on pelleted rations.

Long et al. (1955) fed the ration of long hay, whole grain in three different physical forms, natural, ground and ground and pelleted to lambs and studied the digestibility values. They found that the average apparent digestion coefficients for organic matter, crude protein, crude fibre and NFE were significantly higher ($P < 0.01$) for pelleted ration than for the ground ration.

Bell et al. (1955) observed in lambs fed on pelleted ration containing 65 per cent roughage and 35 per cent concentrate, increased weight gain than lambs given similar but unpelleted ration. The feed was more efficiently utilized when it was pelleted. Further, they found by feeding pelleted ration, the protein and fat were more efficiently digested than in the unpelleted rations. Higher proportion of concentrates in pellets occasionally caused digestible disturbances.

Lindahl and Davis (1955) concluded that pelleting usually reduced the moisture content of feed mixtures even when steam or water was used in the process. There was a trend towards

higher digestibility of ether extract and lower digestibility of crude fibre and only slight differences if any were noted among TDN values between the pelleted and unpelleted feeds.

Clanton et al. (1959) studied the digestibility and efficiency of pelleted and chopped rations for growing and finishing beef cattle and found that the dry matter and energy in the chopped roughage rations were more digestible than those in the pelleted roughage rations. Gains and feed efficiency were similar. Further, they concluded that pelleting did not change the nutritive value of the ration for growing calves.

Hartman et al. (1959) fed 698 lambs on pelleted and unpelleted rations that contained either 29 or 59 per cent alfalfa hay. Pelleting increased gain on the high roughage but decreased on the low roughage ration. They concluded that the increased consumption of the pelleted high roughage ration was mainly accounted for the increased gain. Efficiency of feed conversion of either ration was not significantly affected by pelleting.

Meyer et al. (1959) reported a higher nitrogen digestibility for the pelleted alfalfa hay than chopped hay. TDN, DE, ME and NE content were not significantly different between the pelleted and chopped hay.

Perry et al. (1959) found that lambs whose pellets contained 60 to 40 per cent roughage to concentrate ratio grew

more rapidly (P/ 0.01) than lambs receiving ration containing 40 to 60 per cent roughage to concentrate ratio. Further, they noticed that even though lambs fed 40 per cent roughage pellets gained less rapidly (P/ 0.05), the dressing percentage was greater (50.3% for 60% roughage lots Vs. 52.1% for 40% roughage lots) than for the more rapid gaining lambs fed on the 60 per cent roughage level pellets.

Weir et al. (1959) conducted a lamb digestion trial to study the alfalfa in chopped and pelleted form. They obtained uniform protein digestibility, low fiber digestibility, for the pelleted rations compared to the chopped rations and stated that pelleting did not affect the total digestible nutrient content of the lamb rations.

Reynolds and Lindahl (1960) found that pelleting of the hay resulted in an increase in the other extract and a decrease in the crude fibre digestibility. The digestion coefficients for crude protein and nitrogen free extract were significantly higher in the ground or pelleted hays when fed to sheep.

Thomas et al. (1960) found that lambs fed rations containing 30 and 35 per cent hay in a completely pelleted ration made more efficient gains as compared to a conventional ration.

Brent et al. (1961) noticed a wide variability of per cent nitrogen retained between individual lambs in a digestion study

with nine lambs fed complete pelleted rations containing 10, 20, 30, 40, 50 or 60 per cent sorghum grain and the remainder alfalfa hay.

McCrosky et al. (1961) fed 48 steers individually in two trials to study the effect of pelleted ration with 1:4 and 4:1 concentrate to roughage ratio on feed lot performance and carcass merits. They observed that the rate of gain and feed intake was slightly increased ($P < 0.01$) by pelleting 1:4 ration. Pelleting the 4:1 ration resulted in no significant change in feed intake. Feed efficiency on both rations was improved slightly by pelleting and dressing percentage was unaffected by pelleting.

Trent et al. (1961) conducted an experiment with nine lambs by feeding pelleted rations containing various levels of concentrates. They found highly significant ($P < 0.01$) difference in digestible energy with an increase in an almost perfect linear relationship with increase of concentrates in rations. The digestible dry matter was correlated with digestible energy on each individual ration and highly significant relationship between the two measurements were found.

Alexander and Hent-ges (1962) observed increased intake by cattle and sheep when hay was ground or pelleted.

Beardsley (1964) reviewed the research with pelleting and concluded that feed intake, daily gain and feed efficiency of cattle and sheep generally increased when forage was pelleted eventhough the digestibility was depressed.

Moore (1964) summarised the effect of pellet feeding in comparison with chopped or long hay. Pellet feeding reduced the time of prehension, mastication, saliva secretion, time of rumination, acetate to propionate ratio and crude fibre digestibility. On the contrary it increased the rate of fermentation in rumen, concentration of rumen volatile fatty acids, rate of digestion in rumen and rate of passage of feed particles from the rumen. The feeding value of poor quality forages was improved by pellitization, whereas there was no improvement in feeding value when good quality forages were pelleted.

Fontenot and Hopkins (1965) reported that pelleting the complete ration did not alter the feed lot performance in lambs. However, there was a significant increase in feed efficiency by 16 per cent.

Jordhan and Hanke (1965) reported that lambs on complete pelleted rations containing 50 to 100 per cent roughage resulted in an increased feed consumption and significantly greater gains as compared to rations containing long chopped hay or shelled corn.

Beacom et al. (1973) conducted experiments in growing lambs using rations in ground and pelleted forms containing 40, 70 and 90 per cent wheat grass and reported that pelleted feeds increased dry matter intake, rate of gain and feed efficiency by 15, 47 and 23 per cent, respectively. Further, no significant effect was recorded due to level of roughage in the ration and interaction between the ration form and roughage level.

Bhattacharya and Khan (1973) fed pelleted rations containing 45 per cent wheat straw and varied levels of urea (0.75 to 2.0%) in experimental rations with soyabean meal as a protein supplement in the control ration to fattening sheep. They observed that the average daily gain and daily feed intake did not show any marked differences between groups and the feed required was least in 1.5 per cent urea fed group.

Viktrov et al. (1974) conducted digestion, metabolic and growth trial in cattle using beet pulp, oats and maize. They concluded that there was no difference in digestibility among the groups but with pellets, utilization of nitrogen was better. Deposition of calcium and phosphorus was some what poorer in the controls than with pellets. Carcass yields and weights of internal fat were greater with pellets.

Ibadov et al. (1977) in a digestibility trial with sheep fed complete pelleted diet containing 20 to 50 per cent dry

matter replaced with cotton seed residues and recorded greater digestibility of Nitrogen-free extract and less digestible protein per kg dry matter with the cotton seed residues than those without them.

Gotsulenko et al. (1977) in a trial with 400 rams over one year old, 200 young rams upto one year and 100 culled ewes, compared pellets or green feeds and concentrates and recommended that best results for practical feeding were obtained by giving sheep during the first month of fattening 0.8 to 1.6 kg pellets daily with green feed and pellets alone towards the end.

Nabi (1977) allowed three different breeds of sheep namely Kashmir merino, Stavropol and Russian merino to graze on pasture herbage exclusively for a period of 130 days and reported a daily gain of 111.42, 110.86 and 115.40 g for the three breeds, respectively. He observed highest live weight gains in all the three breeds during July and early August when high crude protein content (17%) and low crude fibre content (18%) were found in the herbage and the live weight was negative during October when herbage was ripe with high crude fibre (26.86%) and low crude protein (7.6%).

Bush et al. (1978) compared pelleted complete feed containing 13 and 15 per cent crude protein, mash concentrate containing 13 per cent CP to be fed with long timothy hay, and pelleted complete feed formulated to meet the requirements

using lambs and concluded that pelleted complete rations are advantageous in a fattening lambs programme both on performance and economic basis and that there was no advantage of increasing the crude protein content of the pelleted complete ration from 13 to 15 per cent.

Ninova (1979) fed 3 groups of male lambs for 60 days with 45 per cent lucerne hay and 55 per cent concentrates. For the first group 35 per cent of lucerne was chopped and 10 per cent was ground and pelleted, respectively along with the concentrate. The average daily gain was 195, 200 and 255 g respectively for the three groups. The feed conversion ratio was 4.7, 4.5 and 3.9 for the three groups, respectively.

Leushin and Levakhin (1979) gave pelleted feed mixtures with small quantities of roughages in a traditional form to Hereford male calves, 3 to 8 months old, had no adverse effect on physiological state or on growth. Calves given the pelleted mixtures gained more weight daily than calves given traditional feed.

Baran et al. (1980) studied rumen motility in sheep given pelleted feeds. Frequency and intensity of rumen contractions were reduced with pelleted feed but without damage to health or dysfunction of the digestive tract. During feeding, number of secondary rumen contractions increased and frequency for both groups was maximum at one hour, upto one hour intensity was about the same with both forms of feed.

Church et al. (1980) fed ewe and wether weanling lambs a pelleted diet containing 60 per cent roughage and 40 per cent concentrate for 12 hours per day and reported a daily gain of 285 and 230 g for males and females, respectively.

Kovalskii et al. (1980) fed young cattle on complete pelleted diet of wheat plants cut at waxy-milk ripeness stage and found that dietary nutrients were more efficiently utilized and growth was faster than those on a control (traditional X diet).

Mahdalik (1980) observed that when finely ground feed was given the rumen activity was interrupted and digestibility and health disorders followed and concluded that the pellets should have a coarse structure and adequate content of fibre.

Chavrenko et al. (1980) fed sheep throughout the year on a pelleted diet and reported that estimated morphological and biochemical values of blood and mineral composition of bones at various growth phases did not show any deviation from the normal

Meged (1980) recommended that feeds for young lambs should not include more than 60 per cent of dry matter as pellets.

Boiko et al. (1981) in a trial fed black pied bulls, loose pelleted or briquetted feed mixture which contained straw treated with 27 per cent caustic soda and reported that the digestibility and utilization of dietary nutrients were better with the pelleted and briquetted mixtures than with loose mixture.

Plickova *et al.* (1981) reported that the rate of gain of calves was greater by 231 g daily when fed with the complete pelleted feed than that of the traditional multi-component fed calves. Further, foliaceous papillae in the rumen of calves given the complete pelleted feed were poorly developed.

Reddy and Reddy (1981) observed the growth rate and digestibility of four complete mash rations containing crop residues and agro-industrial by-products in Deccani sheep. No significant differences were observed in average daily gain and feed intake and digestibility coefficients of dry matter, crude fibre, ether extract and nitrogen-free extract of control and the experimental groups. All the four groups showed positive nitrogen, calcium and phosphorus balances.

Satyanarayana (1981) studied *in vitro* digestibility of three different feeds namely mixed grass hay, complete feed mash and complete feed pellets using two fistulated buffalo bulls as donors. He observed that *in vitro* dry matter (IVDMD) digestibility of mixed dry grass hay was very poor because of its poor nutrient make up. Significant ($P < 0.01$) differences were found in digestible dry matter, digestible energy, total digestible nutrients and estimated net energy values between mixed dry grass hay, complete feed mash and complete feed pellets containing 65 per cent mixed dry grass hay.

2.4 UTILIZATION OF MOLASSES IN RUMINANT RATIONS

Molasses is an efficient, economical and a readily available source of energy which helps in the utilization of non-protein nitrogenous substances like urea, in rations of ruminants and also helps in enriching fibrous crop-residues.

Willet et al. (1946) reported that when cane molasses constituted 25 per cent of the concentrates in the ration of dairy cows, urea was utilized very efficiently.

Knodt et al. (1950) reported that ammoniated cane molasses, when used at 10 per cent of the ration of dairy calves, produced good growth and was used as a partial substitute for protein.

Mather and Bender (1951) fed molasses ad libitum to growing heifers by replacing 4 lb of grains in ration and found that there was no significant difference in growth rate. The molasses consumption ranged from 6.1 to 20.6 lb per day.

Mather et al. (1953) observed significantly higher intake of hay when sprayed with molasses but there was decreased intake of silage which was sprayed with molasses in dairy cattle.

Lofgreen and Otagaki (1960) fed different levels of molasses to fattening steers and found that 10 per cent level of molasses significantly increased fat deposition but did not increase significantly total gain. But with 25 and 40 per cent level,

they observed lower rates of gains, lower fat deposition than that of basal diet.

Komkrist et al. (1966) fed molasses at 13 or 20 per cent along with roughage and concentrates in complete mixture or separately to 12 lactating cows. They found no significant effect of the treatments on production of fat corrected milk or total solids, butter fat or protein content. By feeding 20 per cent molasses in complete mixed feed, they observed significantly less solids-not-fat and depression in daily intake.

The same authors observed increased organic matter and nitrogen-free extract digestibilities with increase of molasses when hay, concentrates and molasses were given in a mixture. But the digestibility of crude protein decreased when the molasses, hay and concentrates were fed separately.

Ellis and Huston (1967) reported that a dry molasses product was prepared using ground waste paper which appeared to be palatable when included in the diet of lactating cows. Yearling heifers gained 0.8 kg daily on ration which included 1.1 kg of paper and 1.7 kg molasses.

Mosler et al. (1967) found that including molasses in the diet containing waste paper appeared to be palatable in cows.

Britton et al. (1968) reported that cane molasses stimulated urea nitrogen utilization and fibre digestion in whether lambs fed semi-purified, all urea supplemented rations.

Hatch and Reeson (1972) fed 5, 10 and 15 per cent cane molasses by replacing grain and found that 5 per cent molasses had no significant effect on any of the parameters studied. Nitrogen retention, apparent digestibility of dry matter and energy increased significantly ($P < 0.05$) when 10 and 15 per cent molasses were added to the ration. Further, they observed that the quality and per cent of butyric acid increased significantly when 15 per cent molasses ration was fed but other parameters did not change by addition of 15 per cent molasses to basal diet. They concluded that the cane molasses energy value was not inferior to corn.

White et al. (1973) reported that dry matter, energy and nitrogen-free extract digestibilities were increased when the molasses content was increased from none to 5 or 10 per cent and from 5 or 10 to 20 per cent. Crude fibre digestibility increased when 5 per cent molasses was added but further increments of molasses gave no more increase.

Heinemann and Hanks (1977) indicated that approximately 10 per cent replacement of the concentrate was the satisfactory upper limit for molasses in steer finishing diets.

Rubio (1978) found that utilization of urea nitrogen was increased by starch rather than cane molasses.

Reddy and Reddy (1979) conducted a trial on sheep with 2 per cent urea and 10 per cent molasses supplementation to paddy

straw and tapioca residue and recommended that the above treated material could be safely fed to sheep. Further, they observed better growth rate and feed efficiency when concentrate mixture was supplemented to urea-molasses enriched paddy straw.

Johri et al. (1982) in a trial with calves fed 0, 14, 21 and 28 per cent molasses in the ration and found no significant differences in dry matter intake, water intake and mean digestibility of dry matter, crude protein, crude fibre and nitrogen-free extract between the groups. The digestibility of ether extract was significantly low in group 2 than in the other groups.

2.5 EFFECT OF UREA-MOLASSES IMPREGNATION ON LOW-QUALITY ROUGHAGES

Urea-molasses impregnation of inferior quality roughages has been widely reported to have a beneficial influence for ruminants.

Satapathy and Laffel (1962) observed that lambs fed pellets containing 75 per cent corn cobs, 25 per cent corn meal and a supplement containing 60 per cent cane molasses, 30 per cent water, 10 per cent urea had a significantly higher rate of gain in a 42 day trial than lambs fed no urea in their supplement. Molar proportions of rumen VFA were also higher in the urea supplemented group indicating better utilization of poor quality roughages when supplemented with urea.

Gupta (1966) reported that consumption of wheat bhoosa and paddy straw in buffaloes increased by 11 per cent when supplemented with 10 per cent molasses. A further addition of urea at the rate of 2 per cent of the ration increased the overall consumption by 28 per cent for wheat bhoosa and 15 per cent for paddy straw.

Ichhaponani and Sidhu (1966) investigated the voluntary intake of low-grade roughages (wheat straw) feeding to cattle and buffaloes by addition of different levels of urea. They observed that the dry matter intake and digestion of dry matter, crude fibre and crude protein increased with increase of urea nitrogen from 0 to 100 g per animal per day.

Lesch and Pieterse (1968) observed that addition of urea to a basal diet of chaffed hay increased the intake of dry matter, giving higher positive nitrogen balances. The digestibilities of dry matter and ether extract tended to decrease as the intake of urea nitrogen increased.

Gupta et al. (1969) found that when 2 per cent urea and 10 per cent molasses were added, the intake of dry matter increased from 1.10 to 1.26 kg per 100 kg body weight on rice straw and from 1.08 to 1.38 kg on wheat straw.

Gupta et al. (1971) fed three groups of growing buffalo calves with wheat straw fortified by 10 per cent molasses,

10 per cent molasses plus 3 per cent urea or 10 per cent molasses plus 5 per cent urea, respectively. They observed that intake of roughage was significantly improved when urea was supplemented. The digestibility coefficients of dry matter, crude fibre and crude protein were significantly improved when urea was added to wheat straw. There was improvement in the growth rate when three per cent urea was supplemented in a 90 day growth study. However, 5 per cent urea supplement did not yield any significant improvement.

Bhattacharya and Pervez (1973) in their metabolic trials with lambs fed on rations containing 50 per cent wheat straw or barley supplemented with 0, 1 and 2 per cent levels of urea and found no significant difference in the digestibility of various nutrients. Crude fibre and ether extract digestibility increased upon urea supplementation. No significant difference was found in nitrogen retention and metabolizable energy values among the treatments.

Coleman and Barth (1974) indicated that the retention of absorbed nitrogen, retention of nitrogen and net protein utilization decreased as the percentage of dietary nitrogen supplemented by urea increased from 0.45 per cent to 2.60 per cent.

Singh and Kuswaha (1974) found that paddy straw supplemented with 1 per cent urea and 18 to 30 per cent molasses with mineral mixture and vitamin A supplement, provided

minimum nutrient requirement recommended by Morrison for maintenance of 350 kg steers.

Moreira et al. (1977) fed three groups of sheep either poor pangola hay alone, hay plus molasses or hay plus molasses plus urea. The addition of molasses or molasses plus urea increased significantly dry matter and organic matter digestibility. The addition of molasses, decreased the protein and fibre digestibility. Addition of molasses and urea increased protein digestibility significantly and fibre digestibility slightly. The addition of molasses or molasses plus urea did not affect digestibility of ether extract. Nitrogen-free extract and energy digestibility increased significantly.

Singh and Tarsaul (1977) observed that the digestibility coefficient of crude protein increased as urea level increased from 2 to 4 per cent of wheat straw.

Sandev et al. (1978) observed that nitrogen in urine/g nitrogen intake or digestible nitrogen tended to increase with pelleting for diets with urea and decrease with pelleting for diets with sunflower oil meal. The amount of nitrogen retained decreased with urea diets and increased with sunflower meal diet.

Singh and Patnayak (1980) based on their experimental results, recommended that the costly groundnut cake could be

replaced by addition of 50 per cent urea nitrogen (adding about 2.6 per cent urea in concentrate supplement) to lamb rations safely without any deleterious effects on health, growth and wool production.

Veira and Macleod (1980) evaluated the effect of rolling or grinding maize, and of the addition of 0 or 1.2 per cent urea, and noted that the inclusion of urea increased dietary protein from 9.5 to 12.8 per cent, significantly increased the growth rate from 0.72 to 1.06 kg/day and significantly decreased the intake of feed dry matter from 4.68 to 3.69 kg/kg gain.

Yeo-Tong Yah et al. (1981) fed creolex Friesian heifers for 84 days diets with 0, 1.25, 2.50, 3.75 or 5.0 per cent of urea in liquid molasses and observed that the daily live weight gains were significantly greater with urea at 1.25, 2.50 or 3.75 per cent compared with 0 or 5 per cent. Further, they found that the intakes of molasses and total dry matter and feed conversion efficiency were greatest with 2.5 per cent urea.

Hadjipanayiotou (1982) sprayed chopped barley straw with 10 per cent urea solution, 400 ml/kg and stored in sealed containers for 90 days. The overall increase in digestibility of treated over untreated was 11 per cent units. Voluntary intake and CF and DM digestibilities of treated straw were increased by 47, 40 and 26 per cent, respectively over the untreated straw with sheep.

Lurdi and Rasdan (1982) fed Tharparkar cows and Murrah buffaloes on 4 levels of urea (2.25, 3.40, 4.50 and 5.50%) and 15 per cent sugarcane molasses in the concentrate mixture and wheat straw was the only roughage. Further, they reported that pH of rumen content never exceeded 7.0 in any treatment and the pattern of fermentation in the rumen was almost same in both the species.

2.6 NITROGEN FRACTIONS IN THE RUMEN

The ruminant animals on its natural diet of forage, ingests a mixture of both protein and non-protein nitrogenous substances. The ability of rumen microbes to modify, alter or to supplement the amount of nitrogen that becomes available to the animal has been recognised (Annison and Lewis, 1959). The process in the rumen consists of conversion of dietary and endogenously secreted nitrogenous compounds into degradation products such as peptides, amino acids and ammonia. Some of these products, especially ammonia may be absorbed directly across the rumen wall, but under normal circumstances most of the ammonia is used by the rumen bacteria for the synthesis of their own body proteins.

2.6.1 Proteolysis and Deamination

Sym (1938) demonstrated the presence of highly active proteinases in the reticulo-rumen and considered these enzymes

to be of microbial origin. Pearson and Smith (1943) showed that rumen bacteria and protozoa possessed proteolytic activity. Warner (1956) concluded that atleast 80 per cent of the proteolytic activity of reticulo-rumen was due to bacteria alone.

McDonald (1948, 1952) found that ammonia was the major end product of protein degradation in the rumen and recognised its importance in rumen metabolism. Annison (1956) established the presence of peptides and amino acids as end products of proteolysis in rumen. Measurable quantities of both amino nitrogen and diffusible peptide-nitrogen were always present in the rumen and their concentration increased by 5 to 10 fold after feeding.

In ruminant the ingested proteins, like other feedstuffs are subjected to microbial attack and extensively degraded before passing on to the abomasum and small intestine. Although degradation of dietary protein in the rumen is of considerable importance with regard to low quality proteins, it may be a wasteful process with regard to good quality proteins.

Various techniques for protecting dietary proteins from ruminal degradation have been established. These include heat treatment, use of tannins (Bhargava, 1973) and formaldehyde (Kaufmann, 1979). In addition, various processing techniques

such as grinding, pelleting, flaking, extrusion cooking etc., may alter the protein degradation in the rumen.

2.6.2 Absorption of Ammonia and Reuse of Urea Nitrogen

Normally most of the ammonia liberated in the rumen will be utilized by the microbes for the synthesis of their own body proteins. But excess ammonia finds its way to liver via portal circulation across the rumen wall and gets converted into urea, a part of which re-enters rumen either through saliva or across the rumen wall.

Lewis et al. (1957) observed that changes in the rumen ammonia concentration of sheep fed various diets paralleled changes in portal blood ammonia concentration, indicating rapid transfer of ammonia across the rumen epithelium into venous blood draining the rumen. McDonald (1948) calculated the quantities of ammonia nitrogen absorbed from the rumen to be of the order of 4 to 5 g per day.

Bloomfield et al. (1963) observed that ammonia transfer across the rumen epithelium is affected by rumen pH. Ammonia being weak base with a PKa of 8.8 at 40°C, the increased absorption of ammonia at higher pH was probably due to increase in ammonia in relation to ammonium ion which may penetrate lipid layers of mucosa more rapidly. Bloomfield et al. (1966) indicated that under conditions of high protein or urea diets, more ammonia might be absorbed from the rumen, reducing the synthesis of microbial cells.

Kaufmann (1979) observed that at 13 per cent crude protein level in the dry matter of whole ration, there was no net loss of nitrogen due to ammonia absorption in the rumen. When the dietary concentration of crude protein exceeded this level, there was loss of nitrogen from the rumen in the form of ammonia absorbed into the system which was subsequently excreted as urea in urine.

2.6.3 Microbial Protein Synthesis

Rumen microbial proliferation requires energy (ATP), a source of sulphur, branched chain fatty acids and amino acids and or ammonia in addition to other necessary carbon skeletons. Huhtanen (1954) found that fermentation products found in large amounts such as acetate and carbondioxide can be used as precursors for synthesis of necessary carbon skeletons for microbial protein synthesis. Lewis (1965) questioned the involvement of amination, specifically transamination in the microbial bio-synthesis of amino acids, in that transamination usually was associated with an active oxidative metabolism. He suggested that other mechanisms, such as glutamine synthatase which effectively fix ammonia into an organic compound could be operative in the rumen.

Wright (1967) observed that the products of initial degradation of protein in the rumen, namely peptides and amino acids can be directly incorporated into bacterial cells.

Chalupa (1968) suggested that the main function of amino acids in the rumen may not be to provide amino nitrogen alone but also to provide carbon skeletons, following their deamination. Waldo (1968) indicated that balance between the amounts and availability of nitrogen and energy to the rumen microbial population had an important effect on utilization of both energy and protein. Chalupa et al. (1970) showed that amination and transamination reactions appear to be major mechanisms for ammonia assimilation by rumen bacteria.

Mathison and Milligan (1971) found that 50 to 65 per cent bacterial nitrogen and 31 to 55 per cent of protozoal nitrogen was from ruminal ammonia pool.

Satter and Slyter (1974) found that increasing ammonia concentration beyond 50 mg ammonia nitrogen per litre of rumen fluid had no effect on in vitro microbial protein synthesis. Hoffler et al.(1976) confirmed this concept by in vitro studies.

Mehreze et al. (1977) observed that a minimal ammonia concentration for maximum rate of fermentation was of the order of 235 mg per litre of sheep rumen fluid maintained on study levels of ammonia concentration. The predicted ammonia concentration of 235 mg per litre of rumen fluid was high when compared to in vitro studies which showed 50 to 60 mg per litre of rumen fluid for maximum microbial protein synthesis.

When nitrogen was not the limiting factor for microbial growth, there was evidence to suggest that amounts of microbial protein synthesized was directly related to the amount of organic matter fermented in the rumen. Under most practical situation, about 200 g microbial protein was synthesized per each kg of apparent digestible organic matter fermented in the rumen (ARC, 1980). Norhami et al. (1979) using (15 %) H_2SO_4 (30% enriched) estimated the mean rate of ammonia nitrogen incorporation into microbial cells to be 20.12 mg per hour per kg of rumen content, which was equal to 59.9 g of microbial nitrogen daily. The microbial cell yield per mole ATP (YATP) was 13.6 g.

Nizwicki et al. (1980) found that non-ammonia nitrogen concentration in the rumen increased by an average of 23 per cent with urea supplementation. They showed enhanced bacterial protein synthesis with added urea. Vieira et al. (1980) observed that when protein was greater than 12 per cent of the diet, there was no effect of diet on abomasal flow of nitrogen and bacterial origin. There was no apparent effect of rumen ammonia concentration on the rate of microbial synthesis inspite of low levels (5 mg %/100 ml) observed with low crude protein diets.

2.6.4 Forms of Nitrogen in Rumen

The total nitrogen in the rumen fluid can be categorised as bacterial nitrogen, ammonia nitrogen, residual nitrogen

and food and protozoal nitrogen. Residual nitrogen consists of both amino and diffusable peptide nitrogen along with soluble proteins.

The distribution of nitrogen in the rumen fluid was first studied by McDonald (1952) in sheep fed casein and zein as protein sources. When zein was included in the diet, ammonia concentration was extremely low after feeding while the residual nitrogen levels showed no change. In sharp contrast, casein was more rapidly degraded with liberation of ammonia and the residual nitrogen showed a rise of comparatively shorter duration. McDonald (1952) concluded that slower rate of release of ammonia from zein permitted sufficient time for bacteria to trap the released ammonia for microbial protein synthesis.

McDonald (1952), Warner (1956) and Annison (1956) noted that addition of readily available carbohydrates considerably depressed the formulation of ammonia. Phillipson et al.(1959) suggested that the decreased ammonia concentration when starch was added to a high protein ration, could partly be due to immediate availability of energy needed for micro-organisms to trap the released ammonia.

Agrawala et al. (1963) made a quantitative study on the microbial protein synthesis in calves, fed natural and purified rations. They found that the rumen micro-organisms synthesized

33 to 109 g of protein within 6 hours after feeding, with urea as the nitrogen source.

Annison (1956) examined the rates of breakdown of several proteins using washed cell suspensions obtained from sheep fed different diets. He analysed ammonia, amino and peptide nitrogen in rumen liquor. Both amino nitrogen and diffusible peptide nitrogen were always present in rumen liquor and their concentrations increased by as much as 5 to 10 fold, after feeding. Gray and Pilgrim (1956) and Gray, Pilgrim and Weller (1958) examined the nitrogen-lignin ratios of feed and abomasal contents of sheep, fed various diets. They found that there was considerable variation in the amount of total nitrogen reaching abomasum with rations of alfalfa hay and alfalfa hay + wheat hay, the values being 40 and 60 per cent, respectively.

Waller et al. (1958) distinguished bacterial protein from plant and protozoal protein by measuring the amount of 2, 6 diamino pimelic acid (a component of cell of most bacteria and blue green algae and not of animals and higher plants). Approximately 27 per cent of rumen nitrogen was in the form of plant nitrogen at 2 hours, 20 per cent at 7 hours, 16 per cent at 10 hours and 11 per cent at 16 hours and 24 hours after feeding.

Moore and King (1958) found that the concentration of soluble protein and soluble non-protein nitrogen in the rumen

were maximum at one hour after feeding and then declined gradually. The gradual decline was accompanied by a concomitant increase in ammonia concentration. But peak ammonia concentrations were obtained at 2 hours after feeding followed by a gradual decline until the next feeding.

Blackburn and Hobson (1960) showed in sheep fed casein that the decrease in non-ammonia, non-protein nitrogen was accompanied by an increase in ammonia concentration. Briggs et al. (1964) observed a significant increase in ruminal ammonia when urea replaced protein concentrations in roughage basal rations for cattle and sheep.

Chou and Walker (1964) showed that total nitrogen and its constituents, namely ammonia, non protein nitrogen and residual nitrogen were fairly uniform for a given diet. Elliot and Topps (1964) observed that total nitrogen and ammonia concentration of rumen fluid were positively correlated with intake of crude protein. Microbial protein nitrogen varied from 45 to 65 per cent of total nitrogen and was negatively correlated with ammonia nitrogen.

Davis and Stallcup (1964) found that sheep fed basal diet alone showed very low concentration of rumen protein, ammonia and residual nitrogen when compared to those fed either basal diet plus casein or urea diet. In latter experiments Davis and Stallcup (1966) studied the utilization of

nitrogen of toasted foods by feeding cotton seed hulls plus soyabean meal or toasted soya flakes. They observed that all the nitrogen fractions in the rumen including the protein nitrogen were higher with soya flakes diet. This was interpreted to mean that ammonia nitrogen liberated from toasted foods was utilized more effectively by rumen micro-organisms than that of other diets.

Peretjagen (1966) examined the effect of carbohydrate supplementation on nitrogen utilization in wethers, by estimating the total nitrogen, residual nitrogen and ammonia nitrogen, in rumen fluid. His observations indicate that all the nitrogen fractions examined were greater, when sugar beet was included in the ration. However, the synthesis of microbial protein was more rapid when potatoes were added.

Thompson et al. (1967) observed that steers fed mash ration had greater concentration of non protein nitrogen and ammonia nitrogen than those fed pelleted ration. There was only slight increase in protein nitrogen due to pelleting of ration.

Langer et al. (1969) studied the production of TCA insoluble protein, ammonia and residual-N on supply of restricted amounts of available carbohydrate in the ration of buffalo and zebu and found that the microbial protein synthesis from the dietary-N was higher at 2 hour after feeding in the buffalo,

while in the zebu it was negligible and that the dietary nitrogen in the zebu was mostly liberated as ammonia upto 4 hours after feeding.

Misra and Ranhotra (1969) found peak concentration of ammonia nitrogen and TCA insoluble protein nitrogen 2 hours after feeding and from then onwards, the values returned to prefeeding levels after 8 hours. When additional energy was provided in the ration, all the components of nitrogen except ammonia nitrogen increased appreciably.

Singh et al. (1968) studied nitrogen utilization in zebu cattle and buffaloes under urea and non-urea feeding regimes. The concentration of total nitrogen, TCA-N, residual nitrogen, ammonia nitrogen and feed and protozoal nitrogen were higher in animals fed urea. Except feed and protozoal nitrogen, the other fractions were higher in buffaloes than in zebu cattle, irrespective of the source of nitrogen, indicating that the utilization of nitrogen was better in buffaloes than in zebu.

Dror et al. (1970) showed that in animals maintained on exclusively hay diet, the concentration of amino nitrogen, diffusible nitrogen and diffusible peptide nitrogen increased while those maintained on concentrates alone showed markedly lower values of various soluble nitrogen fractions. They attributed higher concentrations of various soluble fractions of nitrogen in hay fed sheep to high NPN content of hay diets.

Gupta et al. (1970) observed an increment in the level of molasses from 10 to 15 per cent in wheat bhoosa impregnated with 1.5 per cent urea, resulted in reduced ammonia levels in the rumen besides the dry matter consumption of the buffaloes.

Pant and Roy (1970) studied the rumen microbial activity of buffaloes and zebu cattle. The concentration of food and protozoal nitrogen was higher in zebu than in buffaloes, whereas, the concentration of bacterial nitrogen was higher in buffaloes than in cattle. The concentration of soluble nitrogen (other than ammonia) showed no difference between species but considerable variation between time of sampling relative to feeding time, was noticed. These results indicate that buffaloes utilize ingested protein more efficiently than zebu cattle.

Veselukhin (1970) studied the effect of addition of different starches on nitrogen utilization in bullocks. When the ration contained readily soluble carbohydrates, the synthesis of microbial protein predominated over protein breakdown, thus resulting in very little loss of ammonia to the host-animal.

Ahuja et al. (1972) observed higher concentration of nitrogen in animals fed urea than those fed non-urea rations. The concentration was maintained at a considerably high level

at 8 hours post-feeding compared to 0 hours feeding. True protein concentration increased with increase in post feeding time and non-protein nitrogen increased with increase in urea in ration.

Streeter et al. (1973) found sustained release of ammonia in rumen due to continuous infusion of urea. However, there was no difference in the efficiency of utilization of nitrogen between frequent feeding of urea and twice daily feeding of urea.

Krishna Mohan and Raghavan (1974) fed three levels of protein to cattle and buffaloes and studied various nitrogen fractions in rumen liquor. Time of sampling showed significant difference in total nitrogen and ammonia nitrogen concentration in both species. Concentration of residual nitrogen and food and protozoal nitrogen did not show any particular trend either in relation to the level of protein or time of sampling, both the species. Reddy and Raghavan (1976) observed a significant increase in total nitrogen, TCA insoluble protein nitrogen and ammonia concentration in buffaloes due to change in level and time of sampling.

Baldev Singh and Makkar (1975) observed that the level of ammonia nitrogen and total nitrogen increased markedly in rumen fluid of animals fed urea than in control group. Faster

rate of release of ammonia from urea was responsible for higher values obtained 2 hours after feeding. Significantly higher concentration of total nitrogen, in case of urea than non-urea fed groups at all time intervals, clearly showed the differences in the production and the utilization of nitrogen metabolities. The production of TCA precipitated nitrogen decreased significantly with urea than in control due to higher production of ammonia nitrogen as against its utilization.

Gill and Gill (1975) fed buffaloes with urea fortified pellets and unpelleted rations. Total nitrogen of strained rumen liquor (SRL) was similar in all groups. Maximum values were observed at 2 hours and declined from 2 to 6 hours. At 8 hours, the values were slightly higher than pre-feeding levels. Ammonia nitrogen was maximum at 2 hours post feeding. However, in pelleted rations the ammonia nitrogen concentration reached peak values from 4 to 6 hours. Time of sampling had a significant effect on ammonia levels. Rumen concentration of total nitrogen, non-protein nitrogen and TCA nitrogen of control and urea fed groups did not differ significantly.

Bhargava *et al.* (1977) while comparing oat hay and wheat straw ration observed significant decreased ammonia concentration in oat hay fed group. This was attributed to availability of more keto-acids from oat hay.

Horton (1978) reported that the ruminal NH_3 concentrations were similar when steers were fed with ammonia treated

straw alone or straw plus concentrates and about seven times higher than when untreated straw fed without supplements.

Thatia et al. (1979) observed peak concentrations of total nitrogen, ammonia nitrogen and "PN" at 2 hours post-feeding whereas average protein nitrogen was maximal at 4 to 6 hours after feeding in buffaloes and cattle. Peak values of rumen "NH_3-N" and "PN" at 2 hours post-feeding, which declined thereafter in both the species, differed from those at other hours of post-feeding.

Morris and Mowat (1980) reported that grinding of corn stovers increased rumen acetate, 0.5 hour preprandially or 2 hours post-prandially in steers. Ammoniation increased rumen propionate 0.5 and preprandially but did not significantly affect the remaining rumen parameters.

Prasad (1981) studied the effect of feeding conventional rations and whole ration in the form of mash and pellets on the various nitrogen fractions. The concentration of total nitrogen fractions were found to be significantly higher in the rumen fluid of buffaloes receiving pelleted rations. They were of the opinion that higher crude protein intake might have contributed to higher ruminal nitrogen fractions.

Reddy (1983) conducted experiments to study the effect of mash and pellet feeding on the various nitrogen fractions

in the rumen fluid of sheep. He observed higher concentration of total nitrogen, TCA insoluble nitrogen and residual nitrogen in the rumen fluid of sheep fed pelleted ration. Higher concentration of the aforesaid metabolities were attributed to higher intakes of crude protein in sheep fed pelleted ration.

2.7 pH OF THE RUMEN FLUID

The pH of the rumen does not deviate far from neutrality and is usually within the range of 6 to 7. Phillipson (1942) observed that with decrease in the concentration of volatile fatty acids the pH of the rumen contents rose above pH 7 to a region close to that of blood in fasting sheep. Turner and Hodgetts (1955) examined the role of salivary bicarbonate and phosphate in buffering the rumen contents and concluded that its buffering capacity was due principally to its bicarbonate content.

Briggs et al. (1957) found a strong inverse relationship between the concentration of VFA and lactic acid on the one hand and pH of the rumen content on the other.

Ash and Dobson (1963) felt that the buffering capacity of the rumen fluid does not depend entirely on the saliva secreted, as exchange across the rumen wall of un-ionised acids with bicarbonate accounts for about one half of the acids absorbed.

Pant and Roy (1971) observed a significant decline in the daily mean values of pH of the rumen fluid by altering the frequency of feeding from 2 to 4 times daily at an almost constant dry matter intake.

Reddy and Nair (1971) recorded the lowest pH value at 4 hours after feeding. The pH of the 2 and 6 hour SRL was similar. A greater bicarbonate content in the 6 hours SRL and unequal distribution of the individual fatty acids in the two samples were suggested as possible reasons.

Orskov et al. (1974) found that the pH of rumen liquor was not changed by feeding pellets of rolled or whole barley. Sinha et al. (1977) found that the pH of the rumen fluid increased with alkali treated wheat straw that remained with in the normal physiological range. Garnett et al. (1979) reported that the rumen pH was not different due to consumption of alkali treated (NaOH or NH_3) straw in lambs.

Rai and Pandey (1979) studied seasonal variation in rumen pH of browsing and grazing goats. The pH values were high at zero hour and declined subsequently. The decline was maximum at 8 hours after feeding. The pH values were similar in rainy and winter seasons.

Morris and Mowat (1980) reported higher VFA levels with ammonia treatment of corn stovers in steers.

Deshmukh and Gill (1981) observed a steep fall of pH values between zero hour and 2 hour post-feeding, thereafter the values declined gradually upto 6 hour post-feeding in calves of all age groups, receiving different energy levels.

Pandey and Shukla (1981) studied the effect of feeding various DCP levels and urea on rumen pH and found that the level of DCP feeding had no significant effect on pH while urea incorporation upto 30 per cent of DCP significantly increased the pH.

Reddy (1983) found a significant effect on pH values of the rumen fluid of sheep fed complete mash and pelleted rations at different times of feeding.

2.8 TOTAL VOLATILE FATTY ACIDS (TVFA) IN RUMEN FLUID

Most of the digestible carbohydrates fed to ruminants including cellulose are fermented to volatile fatty acids in rumen by microbes. Branched chain fatty acids are produced by deamination of amino acids. The concentration of the total volatile fatty acids in the rumen fluid is thus dependent of feed intake, nature of the diet, time after feeding and absorption from the rumen.

Annison (1954) examined the changes in VFA content in fasting sheep and found that TVFA level declined steadily, but the concentration of branched chain VFA's showed a slight

increase. Later, Annison et al. (1967) studied the changes in the concentrations of individual fatty acids present in rumen portal and peripheral blood of sheep and observed that considerable portion of VFA was absorbed from the rumen and the TVFA concentration in portal blood and rumen were correlated.

Hinders and Owen (1968) observed that the total ruminal VFA content as well as VFA per kg dry matter post-feeding was greater for hay ration than pelleted ration. Wright et al. (1963) showed that when feed intake was constant the concentration of TVFA in the rumen of lambs fed pelleted or crushed pellets was higher for lambs fed long or coarsely ground hay. Thompson et al. (1966) showed that TVFA concentration was low in steers fed long hay than ground hay.

Langer et al. (1969) observed higher levels of TVFA and acetic acid and lower levels of propionic and butyric acid in the buffalo than in the zebu at all intervals with rations supplied restricted amounts of available carbohydrates.

Rumsey et al. (1970) studied the diurinal variation of ruminal VFA at different intake levels. Total VFA increased as the level of intake increased. A greater change due to level of intake appear to occur in TVFA and the acetic to propionic acid ratio when concentrate based diets were fed.

Pant and Roy (1971) observed a significant increase in ruminal TVFA by changing frequency of feeding from two to

four times a day. The concentration of TVFA showed less fluctuations when fed four times a day as a result of even rate of fermentation and production of greater amounts of VFA. Three distinct peaks were found at 2, 6 and 10 hours after feeding in TVFA concentration. Ahuja et al. (1972) found i significant increase in TVFA concentration in animals maintained on urea diets due to gradual accumulation of VFA in the rumen due to lower rate of fermentation. Bhattacharya and Khan (1973) did not find any significant difference in rumen VFA values in sheep when urea levels were increased in the ration.

Orskov et al. (1974) found that the TVFA concentration was significantly higher when diets were pelleted. The proportion of acetic acid decreased while that of propionic acid increased when diets were pelleted.

Al-Rabbat and Heaney (1978b) reported that the patterns of TVFA levels resulting from feeding the NH_3 treated straw were similar to those usually obtained with diets containing substantial amounts of readily fermentable carbohydrates from grains.

Bines and Davey (1978) fed complete pellets to cows and found that the concentration of TVFA increased after feeding and the changes were greatest for the diets containing no roughage.

Horton (1978) reported that TVFA concentrations were not influenced by feeding ammonia treated straw rather than untreated straw, though they were about 33 per cent higher when concentrates were included in the rations. Ammoniation had no effect on the molar proportions of individual fatty acids in the rumen fluid.

Ahrar and Schingoethe (1979) found that the rumen VFA concentration was similar in cows fed soyabean and heat treated soyabean. Slyter et al. (1979) observed lower concentration of TVFA with low nitrogen intake. Jayasuriya et al. (1980) observed that urea impregnation of green forage resulted in significantly higher VFA concentration and this was attributed to greater microbial activity due to addition of urea.

Morris and Mowat (1980) observed higher TVFA levels with UL_3 treatment and grinding of corn stover with steers with rice straw in lambs (Garrett et al., 1979) and Herera-Saldana et al. (1982) found no difference in TVFA levels with UL_3 treatment and wheat straw with steers.

Prasad (1981) conducted experiments on fistulated buffaloes by feeding conventional ration and pelleted ration and observed that the concentration of TVFA in the rumen fluid was higher in buffaloes receiving pelleted ration than those fed conventional ration.

Reddy and Reddy (1982) observed higher concentration of TVFA production in the rumen liquor of sheep fed complete pelleted rations containing mixed dry grass than those of

the pelleted ration containing teak leaves. They concluded that the pelleted ration containing mixed dry grass hay was more fermentable than that of teak leaves ration.

Linga Reddy (1982) reported higher concentration of VFA in the rumen fluid of sheep during all the sampling times in the complete rations containing wood pulp as compared to mixed dry grass ration. The maximum VFA production was at 4 hours post-feeding in both the experimental rations.

CHAPTER III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

3.1 EXPERIMENTAL RATIONS

The following agro-industrial by-products and crop residues were used as feed ingredients in the formulation of complete rations: dry ground whole cotton plant, rice polishings, wheat bran, groundnut cake, urea and molasses.

3.1.1 Ammonia treatment of Dry Ground Whole Cotton Plant

The whole cotton plants (Gossypium sp.) after the last picking of cotton, were obtained from nearby fields. They were stacked and dried under shade for about 3 weeks so that the moisture content reduced from 30 to 10-12 per cent. Dried cotton plants were ground in a hammer mill using 5 mm sieve. After grinding the material was tested for the presence of cyanogenetic glucosides as per AOAC (1970) method and was found to be free from cyanogenetic glucosides.

Half of the ground whole cotton plants (GWCP) was treated with anhydrous ammonia (NH_3), obtained from M/s. Premier Engineerings, Hyderabad. Polythene bags of 112 x 76 cm with 0.2 mm thickness were used to keep the NH_3 treated material. The cylinder was connected with a hose pipe and a regulator. The hose pipe was inserted into the polythene bag containing weighed quantity of GWCP and then hose pipe and the bags were secured tightly with the help of string and hands.

Five hundred grams of NH_3 was introduced into each polythene bag so that the material gets 3.6 per cent NH_3 on dry matter basis. After injecting NH_3, the bags were sealed and kept for 42 days. During this period, the bags were rotated daily so that free residual NH_3 present may come in contact with the material. After 42 days, the material from the bags was removed and was aerated for 3 days by keeping the material in open air. This treated material was used in the computation of complete rations.

3.1.2 Processing of experimental Rations

Experimental rations were processed at the Pilot Feed and Fodder Processing Plant of Feed Technology section of Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad. The plant has infrastructural facilities for chopping, grinding, mixing and pelleting of concentrates, roughages and roughage based complete rations. The experimental rations used in these studies were:

1. Complete feed (mash) with untreated GNCP,
2. Complete feed (pellet) with untreated GNCP,
3. Complete feed (mash) with NH_3-treated GNCP and
4. Complete feed (pellet) with NH_3-treated GNCP.

The percentage composition of the above rations are given in Table 1. The experimental rations were proportioned in 100 kg batches as per the formulae indicated excluding molasses

Table 1. Percentage composition of complete rations

Ingredient	Ground whole cotton plant			
	Untreated		Ammonia treated	
	Mash 1	Pellet 2	Mash 3	Pellet 4
Dry ground whole cotton plant (untreated)	45.0	45.0	-	-
Dry ground whole cotton plant (ammonia treated)	-	-	45.0	45.0
Urea	1.5	1.5	-	-
Groundnut cake	10.0	10.0	10.0	10.0
Wheat bran	10.0	10.0	10.0	10.0
Rice polishing	17.0	17.0	18.5	18.5
Molasses	15.0	15.0	15.0	15.0
Mineral mixture*	1.0	1.0	1.0	1.0
Common salt	0.5	0.5	0.5	0.5
Hovimix** @ 10 g/qtl.				
	100.0	100.0	100.0	100.0

*Mindif: Contained Ca 20.8%, Phosphorus 6.2%, Salt 35.8%, Iron 0.4%, Iodine 250 PPM, Manganese 740 PPM, Copper 280 PPM and Sulphur 0.15%.

** Hovimix: Contained 40,000 IU Vit.A, 20 mg. Vit. B_2 and 5,000 IU Vit. D_3 per g.

and were mixed in a horizontal mixer. Molasses was pumped from a storage tank to a preheater tank and the preheated molasses was added into the mixer through a dosage tank while mixing. Urea and Novimix were added directly to the mixer dissolving in water. The complete feed was mixed for 10 minutes and collected into gunny bags.

The complete mash feeds 2 and 4 prepared using the above procedure was dropped from the mixer into the bucket elevator and was lifted and conveyed into a hopper over the pellet mill. The mash feed was conveyed from the hopper into the conditioning chamber of the pellet mill through a screw conveying system. The rate of flow of the feed into the conditioning chamber was controlled by wheel valve.

The steam produced from a boiler (capacity 250 lb/hr) attached to the plant was supplied into the conditioning chamber of the pellet mill. The required quantity of steam with 97° to 98°C temperature was supplied into the conditioning chamber through control valve. The conditioned mash at 90° to 92°C temperature and with 16 to 17 per cent moisture was conveyed into the pellet mill and extruded through a ring die with 9 mm holes. The pellets with 9 mm diameter having 83° to 85°C temperature and with 14 to 15 per cent moisture were dropped from the pellet mill into the vertical cooler below the pellet mill.

The cooled pellets were collected into gunny bags from the cooler, stored and used for experimental feeding. The

energy consumed at various processing points in the manufacturing of complete mash and pelleted feed are given in Table 2.

The density of individual ingredients used in this experiment and complete mash and pellets processed in this study were estimated using one cubic foot deelwood box designed for this purpose.

3.2 EXPERIMENTAL STUDIES

Experiments conducted are dealt with under the following headings.

1. Metabolic studies
   a) Murrah buffaloes
   b) Cross-bred calves
2. Growth studies
3. Rumen studies

A brief outline of the experimental techniques and methods of analysis adopted during the course of the present study is given below.

3.3 METABOLIC STUDIES

Four metabolic trials were conducted in a 4 x 4 latin square design in which rows, columns and treatments represented trials, animals and diets.

Table 2. Average power consumption for various processing methods/quintal

Method of processing	Experimental rations			
	1	2	3	4
			(KWH)	
Grinding	4.02	4.02	4.02	4.02
Screw conveyor	0.47	0.47	0.47	0.47
Bucket elevator	0.47	0.47	0.47	0.47
Mixing	0.49	0.49	0.49	0.49
Pelleting	-	2.85	-	2.69
Total	5.45	8.30	5.45	8.14

3.3.1 Experimental Animals

Four adult male Murrah buffaloes with an average weight of 279.5 kg were obtained from the Dairy Experimental Station, Livestock Research Institute, A.P.Agricultural University, Rajendranagar, Hyderabad-30 and were used as experimental animals. The buffaloes were permanently fistulated using ice bags as rumen plugs. The animals were kept under hygienic conditions and in a well ventilated stalls with cement concrete flooring. They were stall fed throughout the experimental period. The four experimental rations were randomly alloted to the four experimental animals. All the rations were offered ad libitum. Water was always made available in clean buckets to each animal throughout the experimental period.

After 20-day preliminary feeding period, the animals were harnessed with urine bags two days before the commencement of actual collection for adjustment and a 7-day collection period was followed for each trial. A 7-day switchover period was allowed between the collections to change the diets.

3.3.2 Sampling of Feed and Feed Residues

Representative samples of each of the 4 rations were taken every day before offering to the animals and were pooled for 7-days, ground in a laboratory wiley mill and preserved in polythene bags for subsequent analysis. Besides,

representative samples of untreated and NH_3-treated GWCP were taken for proximate and Van Soest analysis. Representative samples of residues of each ration were collected every day for dry matter estimation.

3.3.3 Collection of Faeces and Urine

Faeces as and when voided were collected carefully into separate containers which were closed with tight lids to prevent drying of the faeces. The total quantity of faeces voided during 24 hours period was weighed daily at 9.00 A.M. The faeces collected was thoroughly mixed and a representative sample was taken from each animal in a bottle (approximately 500 g) and carefully carried to the laboratory for analysis.

The total urine voided in 24 hours by individual animals was measured daily and representative samples were taken separately in well stoppered bottles.

3.3.4 Aliquoting and Preservation of Faeces and Urine

a) Faeces: For nitrogen estimation, 1/200th part of the faeces voided each day by individual animal was weighed, mixed with sufficient quantity of 25 per cent sulphuric acid and preserved in previously weighed air tight stoppered sample bottles. Daily samples were preserved in the same labelled bottles. After a 7-day collection period, the weights of the samples were recorded.

For dry matter estimation an aliquot of 1/20th part was taken into the petridishes from the individual animals separately and dried in a hot-air oven overnight at 100° to 105°C. The dried samples were pooled, ground in laboratory wiley mill and stored in polythene bags for subsequent analysis.

b) Urine: For nitrogen estimation 1/100th part of the total urine voided daily by individual animal after thorough mixing was pipetted out in duplicate into Kjeldahl flasks containing 30 ml of concentrate sulphuric acid. The aliquots thus pooled in the flasks were maintained separately for each animal.

Similarly, 1/100th part of aliquot was taken in duplicate for mineral estimation in silica crucibles and dried at 100° to 105°C daily and seven day collections were added to the same crucibles. They were ashed in muffle furnace and extracted with hydrochloric acid and preserved for calcium and phosphorus estimation.

3.3.5 Energy Estimation

The gross energy content of the rations and faeces were determined using the parr adiabatic oxygen bomb calorimeter (Series 1200).

Digestible energy content of the experimental rations were estimated by subtracting the gross energy voided in the faeces from the gross energy consumed through feed and the percentage of the digestible energy was calculated. Metaboliz

energy content of the rations were calculated using the factor recommended by TAC, 1975 (DE may be converted to ME by multiplying by 82%).

3.3.6 Analytical Methods

AOAC (1970) analytical methods were followed for estimation of dry matter, organic matter, crude protein, ether extract and total ash. Estimation of calcium was done according to the method of Talapatra et al. (1940). Phosphorus was estimated calorimetrically as per AOAC (1970) procedure. The GNCP, experimental rations and faeces were analysed for cell fractionation using the procedures of Van Soest and Moore (1965).

3.3.7 Statistical Analysis

The experimental data were analysed according to the methods of Snedecor and Cochran (1968).

3.3.8 Power Consumption

The power consumption for various processing methods was calculated as per the formula suggested by Teraj (1965).

3.4 METABOLIC STUDIES IN CROSS-BRED CALVES

A digestion and metabolic trial was conducted on 12 male cross-bred calves (3 from each group of growth trial) to assess the nutrient utilization of the four experimental rations when

the animals were about 200 kg weight in a completely randomised block design. The particulars of the experimental animals and their distribution into different groups are given in Table 3. A 7-day collection was made as detailed in the aforesaid experiments.

3.5 GROWTH STUDIES

Twenty four male cross-bred calves weighing on an average 158 kg obtained from AICRP on Cattle, Lam Farm, Guntur were used for the growth studies. A 90-day feeding experiment was conducted on these animals in a completely randomised block design.

3.5.1 Selection and Distribution of Animals

Twenty four male cross-bred calves of 9 to 12 months age were selected. The animals were randomly alloted to 4 rations, such that each group had six calves, and the average body weights were similar in all the groups. The particulars of the experimental animals and their distribution into different groups are given in Table 4.

3.5.2 Housing and Management

All the twenty four animals were housed in well ventilated individual pens paved with cement concrete (without bedding). The animals were dewormed at the beginning of the experiment. Throughout the experimental period, healthy surroundings and

Table 3. Scheme of distribution of cross-bred calves (Metabolic studies)

Experimental rations							
1		2		3		4	
Animal No.	Weight (kg)	Animal No.	Weight (kg)	Animal No.	Weight (kg)	Animal No.	Weight (kg)
2	199	7	200	16	219	19	213
3	192	9	193	17	190	20	200
5	198	11	210	18	196	23	196
Mean	196.33		203.00		201.67		202.67
S.E.	2.19		3.52		8.35		5.37

Table 4. Scheme of distribution of experimental animals (growth studies)

Experimental rations							
1		2		3		4	
Animal No.	Weight (kg)	Animal No.	Weight (kg)	Animal No.	Weight (kg)	Animal No.	Weight (kg)
1	128	7	164	13	146	19	171
2	173	8	157	14	154	20	158
3	173	9	164	15	151	21	148
4	191	10	147	16	183	22	174
5	153	11	168	17	151	23	153
6	131	12	147	18	161	24	147
Mean	158.17		157.83		158.50		158.50
S.E.±	10.31		3.72		6.22		4.72

proper cleanliness were maintained in the experimental sheds. The animals were also vaccinated against common infectious diseases.

3.5.3 Feeding and Watering of Animals

Rations 1 to 4 were randomly assigned to 4 groups of animals. The experimental rations were fed ad libitum in individual pens. Water was made available in clean buckets to each animal throughout the experimental period. The rations were offered to the animals daily at 9.00 A.M. and 5.00 P.M. The residues left over was weighed in the next morning and in this way the exact quantities of feed consumed daily by each animal was recorded throughout the experimental period.

3.5.4 Live Weight Records

The initial average weights of the calves (averages of three consecutive days) are given in Table 4. Weights of experimental animals were recorded at fortnight intervals throughout the experimental period using Avery Cattle Weigh bridge at 8.00 A.M. before feeding and watering. The final average weights of the calves (average of three consecutive days) are given in Table 48.

3.6 RUMEN STUDIES

A brief outline of experimental techniques and methods of analyses used in rumen studies are given below.

3.6.1 Sampling of Rumen Liquor

Rumen liquor was collected from each animal for 3 days after the 7 day collection period of each metabolic trial. The rumen fluid samples were collected by inserting an aluminium dipper. Care was taken to secure samples of rumen ingesta from the top, middle and lower levels and also the anterior, medium and posterior extremities of the rumen. The ingesta were strained through four layers of muslin cloth and resultant liquid was designated as strained rumen liquor (SRL). About 100 ml of the sample was drawn at each collection into a clean sterile polythene bottle. Daily 4 collections were made, the first before feeding designated as '0' hour and the other 3 after feeding, at 2 hourly intervals i.e., at 2, 4 and 6 hours after feeding. Rumen liquor samples were collected at 9.00 A.M., 11.00 A.M., 1.00 P.M. and 3.00 P.M. every day. pH of the rumen fluid was determined immediately by using Model $\mathrm{H_2}$-BECKMAN glass electrode pH meter. The ammonia nitrogen present in the rumen liquor was estimated immediately after collecting the sample. After adding 1 ml of saturated mercuric chloride solution to check the microbial activity, the strained rumen liquor was stored in polythene bottles and were properly capped and labelled and stored at sub zero temperature for further analyses.

3.6.2 Analytical Methods

Rumen liquor samples were analysed for total nitrogen (Micro-Kjeldahl), TCA supernatant nitrogen and TCA insoluble

nitrogen (Clino et al., 1958), residual nitrogen, food and protozoal nitrogen (Singh et al., 1968) ammonia nitrogen (Schwartz and Schoeman, 1964) and total volatile fatty acids (Parnot and Reid, 1956).

3.6.3 Statistical Analysis

Statistical analysis of the data was done according to the procedures of Snedecor and Cochran (1968).

CHAPTER IV

Results

CHAPTER IV

RESULTS

Two low cost non-cereal based complete rations were formulated using dry ground whole cotton plants (GWCP), a crop residue resulting from cotton crop, untreated or NH_3-treated, as a sole source of roughage i.e., at 45 per cent level in the total ration. These rations were processed into mash and pellet form. The resulting 4 rations were compared in digestion and metabolic experiments along with rumen studies using 4 male Murrah buffaloes and in a growth cum metabolic study experiment using 24 male cross-bred calves for growth and 12 for metabolic study to assess the nutrient digestibility, rumen fermentation and growth performance.

The untreated and NH_3-treated GWCP was analysed for proximate composition and the results are presented in Table 5. The colour of the GWCP changed from light brown to dark brown, due to anhydrous ammonia treatment and the treated material was less coarse and more pliable as compared to the untreated. Ammoniation of GWCP increased the total nitrogen percentage from 1.26 to 2.55. The GWC before and after NH_3-treatment contained 90.73 and 87.88 dry matter, 7.81 and 16.01 crude protein, 41.62 and 39.82 crude fibre, 2.08 and 1.94 ether extract, 42.05 and 35.62 nitrogen-free extract and 6.44 and 6.61 total ash respectively. The calcium and phosphorus contents were 1.33 and 2.15 per cent in untreated GWCP and 1.39 and 2.18 per cent in NH_3-treated GWCP, respectively.

Table 6. Chemical composition of ground whole cotton plant (% dry basis)

Item	Ground whole cotton plant	
	Untreated	Ammonia treated*
Dry matter	90.73	87.88
Organic matter	90.56	90.39
Crude protein	7.81	16.01
Ether extract	2.08	1.94
Crude fibre	41.62	39.82
Total ash	6.44	6.61
Nitrogen-free extract	42.05	36.62
Nitrogen	1.26	2.56
Calcium	1.33	1.39
Phosphorus	2.16	2.18
Gross energy (Mcal/kg)	4.12	4.18
Van Soest Composition		
Neutral detergent solubles	19.22	23.39
Neutral detergent fibre	80.78	76.61
Hemicellulose	23.52	20.57
Acid detergent fibre	57.26	56.04
Cellulose	42.93	42.79
Lignin	12.96	12.16
Silica	1.37	1.09

*Ground whole cotton plant treated with anhydrous ammonia at 3.5% level on dry matter basis.

The untreated and NH_3-treated GNCP was also analysed for cell fractionations as per Van Soest and Moore (1965) and the results are presented in Table 5. The NDS, NDF, ADF, Hemicellulose, cellulose, lignin and ash contents of untreated GNCP were 19.22, 80.78, 57.26, 23.52, 42.93, 12.96 and 1.37 and of NH_3-treated GNCP were 23.39, 76.61, 56.04, 20.57, 42.79, 12.16 and 1.09, respectively on dry matter basis.

Complete rations 1 to 4 were analysed for proximate composition and cell fractionations. The results are presented in Table 6. The complete rations 1, 2, 3 and 4 contained 89.30, 89.24, 88.97 and 88.71 dry matter; 15.69, 15.98, 15.60 and 15.94 crude protein; 25.13, 24.81, 24.04 and 23.98 crude fibre; 3.76, 3.43, 3.94 and 3.79 ether extract; 43.09, 43.44, 42.67 and 42.42 nitrogen-free extract; 12.33, 12.34, 13.75 and 13.87 total ash, respectively. Calcium and phosphorus contents of the complete rations 1, 2, 3 and 4 were 1.45 and 0.73, 1.35 and 0.78; 1.49 and 0.80 and 1.40 and 0.70 per cent, respectively.

The NDS, NDF, ADF, Hemicellulose, cellulose, lignin and ash contents were 43.57, 56.43, 38.85, 17.58, 34.85, 8.10 and 5.90 for ration 1; 48.60, 51.40, 38.95, 12.45, 25.42, 7.66 and 5.87 for ration 2; 45.24, 54.76, 38.74, 16.02, 25.44, 8.14 and 5.16 for ration 3 and 50.04, 49.96, 38.92, 11.04, 25.05, 7.94 and 5.93 for ration 4, respectively.

Table 6. Chemical composition of complete feeds (% dry basis)

Item	Experimental rations			
	1	2	3	4
Dry matter	89.30	89.24	88.97	88.71
Organic matter	87.67	87.66	86.26	86.13
Crude protein	15.69	15.98	15.60	15.94
Ether extract	3.76	3.43	3.94	3.79
Crude fibre	25.13	24.81	24.04	23.98
Nitrogen-free extract	43.09	43.44	42.67	42.42
Total ash	12.33	12.34	12.75	13.87
Nitrogen	2.51	2.56	2.50	2.55
Calcium	1.46	1.35	1.49	1.40
Phosphorus	0.73	0.78	0.80	0.70
Gross energy (Mcal/kg)	3.98	4.02	4.00	4.01
Van Soest Composition				
Neutral detergent solubles	43.57	48.60	45.24	50.04
Neutral detergent fibre	56.43	51.40	54.76	49.96
Hemicellulose	17.58	12.45	16.02	11.04
Acid detergent fibre	38.85	38.95	38.74	38.92
Cellulose	24.85	25.42	25.44	25.05
Lignin	8.10	7.66	8.14	7.94
Silica	5.90	5.87	5.16	5.93

4.1 BULK DENSITIES OF FEED INGREDIENTS AND EXPERIMENTAL RATIONS

The bulk densities of feed ingredients and experimental rations are presented in Table 7. The bulk density of feed ingredients used in the formulation of the experimental rations ranged from 5.9 to 25 kg/cft. The densities of the processed experimental rations were 9.0, 14.2, 9.9 and 16.0 for the rations 1, 2, 3 and 4, respectively.

4.2 COST ECONOMICS

The data on the cost of processing of the experimental rations are given in Table 8. Total power consumed per two shifts of eight hours each was 348.80, 531.30, 370.60 and 553.53 KWH for processing of rations 1, 2, 3 and 4, respectively. Total cost of energy per day was Rs.156.96, 239.04, 166.77 and 249.08 for the rations 1,2, 3 and 4, respectively.

Average processing cost for various complete feeds containing 45 per cent dry ground whole cotton plants was calculated based on two shifts of eight hours each for 300 working days per year. Average production of pellet mill of pilot plant was recorded as 400 and 425 kg/hr for rations 2 and 4, respectively. Total processing cost was Rs.9.71, 17.82, 8.81 and 16.92 per quintal for rations 1, 2, 3 and 4, respectively.

The data on the total cost of experimental rations are presented in Table 9. The existing market prices were used

Table 7. Bulk densities of feed ingredients and experimental rations

Ingredients	(kg/cft)
Ground whole cotton plant (untreated)	6.9
Ground whole cotton plant (Ammonia treated)	6.2
Groundnut cake	16.8
Wheat bran	8.2
Rice polishings	12.5
Urea	20.0
Mineral mixture	25.0
Experimental rations	
1 (Mash)	9.0
2 (Pellet)	14.2
3 (Mash)	9.9
4 (Pellet)	16.0

Table 8. Processing cost of experimental rations

Item	Experimental rations			
	1	2	3	4
I Direct charges				
1. Power cost @ Rs.0.45/KW (Rs.)	156.06	239.04	166.77	249.08
2. Operator (two) @ Rs.20/- per day (Rs.)	40.00	40.00	40.00	40.00
3. Labour (six) @ Rs.10/- per day (Rs.)	60.00	60.00	60.00	60.00
4. Cost of diesel @ Rs.3.16/litre (Rs.)	-	468.94	-	468.94
II Fixed costs*	332.33	332.33	332.33	332.33
III. 1. Total expenditure/day (Direct charges + Fixed costs) (Rs.)	589.39	1,140.31	599.10	1,150.35
2. Production/day for 2 shifts (quintals)	64.00	64.00	68.00	68.00
3. Processing cost/quintal (Rs.)	9.21	17.82	8.81	16.92

* Fixed costs:

1. Depreciation on building and machinery	
a) Depreciation @ 5% per year on 1.00 lakh on civil works for 1 year (Rs.)	5,000.00
b) Depreciation @ 10% per year on 3.5 lakhs on plant machinery (Rs.)	35,000.00
2. Interest @ 10% per year on block investment (Rs.4.5 lakhs) per year (Rs.)	45,000.00
3. Insurance @ 0.6% per year (Rs.)	2,700.00
4. Maintenance @ Rs.1,000/- per month(total per year of 300 working days) (Rs.)	12,000.00
Total per year of 300 working days (Rs.)	99,700.00
Fixed costs per day (Rs.)	332.33

Table 9. Cost of experimental rations

Item	Cost/ quintal	Experimental rations			
		1	2	3	4
		Rs.			
Whole cotton plant (untreated)	10.00	5.40	5.40	-	-
Whole cotton plant (ammonia treated)*	50.50	-	-	22.73	22.73
Groundnut cake	170.00	17.00	17.00	17.00	17.00
Wheat bran	90.00	9.00	9.00	9.00	9.00
Rice polishings	65.00	11.05	11.05	12.03	12.03
Urea	242.00	3.63	3.63	-	-
Molasses	12.72	1.91	1.91	1.91	1.91
Mineral mixture	180.00	1.80	1.80	1.80	1.80
Common salt	40.00	0.70	0.70	0.70	0.70
Tevimix/kg(Vitamin A supplement)	161.00	1.61	1.61	1.61	1.61
Processing cost/quintal		9.21	17.82	8.81	16.92
Total cost/quintal		60.81	69.42	75.09	83.30

* Cost of anhydrous ammonia, Rs.11.00/kg.

for calculating the cost of rations. The cost per quintal of rations 1, 2, 3 and 4 was Rs.60.81, 69.42, 75.09 and 82.20, respectively, inclusive of processing cost.

4.3 DIGESTIBILITY AND METABOLIC STUDIES IN BUFFALOES

4.3.1 Voluntary Feed Intake

An average daily dry matter intake of 6.72, 6.97, 7.58 and 7.70 kg were recorded by the Murrah buffaloes fed rations 1, 2, 3 and 4, respectively. The average total dry matter consumption per 100 kg body weight recorded in this experiment (Table 10) was 2.44, 2.49, 2.71 and 2.76 kg for buffaloes fed rations 1, 2, 3 and 4, respectively. The dry matter consumption was higher ($P < 0.05$) among the animals fed rations containing NH_3-treated GNCP than the rations contained untreated GNCP but pelleting had no effect on dry matter consumption.

4.3.2 Dry Matter Digestibility

Dry matter digestibility coefficients of the Murrah buffaloes are presented in Table 11. The average dry matter digestion coefficients recorded for rations 1, 2, 3 and 4 were 56.33 ± 0.69, 58.31 ± 0.71, 64.25 ± 0.24 and 66.15 ± 0.13 per cent, respectively. The differences in dry matter digestibility coefficients recorded among the four treatment groups were highly significant ($P < 0.01$).

Table 10. Dry matter intake by the Murrah buffaloes as affected by different rations

Ration	Animal No.	Weight	Dry matter intake/day	Dry matter intake/100 kg body weight
			kg	
1	1	233.0	5.60	2.51
	2	216.5	5.69	2.58
	3	298.5	7.28	2.44
	4	380.0	8.40	2.21
	Mean	279.5	6.72	2.44[a]
	S.E.±		0.69	0.08
2	1	223.0	5.58	2.50
	2	216.5	5.30	2.45
	3	298.5	7.25	2.43
	4	380.0	9.73	2.56
	Mean	279.5	6.97	2.49[a]
	S.E.±		1.02	0.03
3	1	233.0	6.02	2.70
	2	216.5	5.89	2.72
	3	298.5	8.18	2.74
	4	380.0	10.22	2.69
	Mean	279.5	7.58	2.71[b]
	S.E.±		2.03	0.01
4	1	233.0	6.40	2.87
	2	216.5	5.69	2.63
	3	298.5	8.42	2.82
	4	380.0	10.30	2.71
	Mean	279.5	7.70	2.76[b]
	S.E.±		1.04	0.85

a,b - values with different superscripts differ significantly

Analysis of variance of dry matter intake per 100 kg body weight

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	0.02	0.007	0.47
Rations	3	0.31	0.103	6.87*
Periods	3	0.02	0.007	0.47
Error	6	0.09	0.015	
Total	15	0.44		

* Significant at 5% level.

Table 11. Average dry matter intake, outgo and digestibility in Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	1	5.00	2.52	3.08	55.00
	2	5.69	2.60	3.09	55.28
	3	7.22	3.10	4.18	57.42
	4	9.40	3.56	4.84	57.62
	Mean	6.72			56.33[a]
	S.E.±	0.69			0.69
2	1	5.58	2.37	3.21	57.63
	2	5.30	2.28	3.03	56.98
	3	7.25	3.01	4.24	58.48
	4	9.73	3.87	5.86	60.23
	Mean	6.97			58.31[b]
	S.E.±	1.02			0.71
3	1	6.02	2.14	3.88	64.45
	2	5.89	2.14	3.75	63.67
	3	8.18	2.88	5.30	64.79
	4	10.22	3.67	6.55	64.09
	Mean	7.58			64.25[c]
	S.E.±	2.03			0.24
4	1	6.40	2.16	4.24	66.25
	2	5.69	1.91	3.78	66.43
	3	8.42	2.88	5.54	65.80
	4	10.30	3.49	6.81	66.12
	Mean	7.70			66.15[d]
	S.E.±	1.04			0.13

a,b,c,d - values with different superscripts differ significantly.

Analysis of variance of dry matter digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	5.42	1.81	3.85
Rations	3	263.56	87.85	186.92**
Periods	3	4.47	1.49	3.17
Error	6	2.83	0.47	
Total	15	276.28		

** Significant at 1% level.

4.3.3 Organic Matter Digestibility

Average organic matter digestibility data of the Murrah buffaloes are given in Table 12. Average daily organic matter intakes were 5.89, 6.11, 6.53 and 6.63 kg with rations 1, 2, 3 and 4, respectively. Average organic matter digestibility coefficients were 57.78 ± 0.64, 59.69 ± 0.73, 65.91 ± 0.49 and 67.75 ± 0.33 per cent among the animals fed rations 1, 2, 3 and 4, respectively. There was a significant difference ($P<0.01$) in organic matter digestibility among the four treatment groups Pelleting and NH_3-treatment of GNCP increased organic matter digestibility.

4.3.4 Crude Protein Digestibility

Daily average crude protein intake, outgo in faeces and digestibility coefficients with the Murrah buffaloes are recorded in Table 13. An average crude protein intake of 1.06, 1.11, 1.18 and 1.23 kg with an average digestion coefficients 63.99 ± 0.36, 66.20 ± 0.94 , 62.10 ± 0.49 and 63.89 ± 0.44 per cent were recorded among the experimental animals fed rations 1, 2, 3 and 4, respectively. Crude protein digestibility coefficients recorded among the four rations were significantly ($P< 0.05$) different.

4.3.5 Crude Fibre Digestibility

Daily average crude fibre intake, outgo in faeces and digestibility coefficients data are presented in Table 14.

Table 12. Organic matter digestibility in Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	1	4.91	2.12	2.79	56.82
	2	4.90	2.13	2.77	56.53
	3	6.38	2.63	3.75	58.78
	4	7.36	3.02	4.34	58.97
	Mean	5.89			57.78[a]
	S.E.±	0.00			0.64
2	1	4.89	2.02	2.87	58.69
	2	4.65	1.92	2.73	58.71
	3	6.36	2.57	3.79	59.59
	4	8.52	3.26	5.27	61.78
	Mean	6.11			59.69[b]
	S.E.±	0.89			0.73
3	1	5.19	1.76	3.43	66.09
	2	5.08	1.77	3.31	65.16
	3	7.05	2.31	4.74	67.23
	4	8.81	3.07	5.74	65.15
	Mean	6.53			65.91[c]
	S.E.±	0.88			0.49
4	1	5.51	1.75	3.76	68.24
	2	4.90	1.59	3.31	67.55
	3	7.25	2.40	4.85	66.90
	4	8.87	2.81	6.06	68.32
	Mean	6.63			67.75[d]
	S.E.±	0.90			0.33

a,b,c,b - values with different superscripts differ significantly

Analysis of variance of organic matter digestibility

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	5.80	1.93	1.87
Rations	3	276.36	92.12	89.44**
Periods	3	3.51	1.05	1.02
Error	6	6.17	1.03	
Total	15	291.84		

** Significant at 1% level.

Table 13. Crude protein digestibility coefficients in the Murrah buffaloes as affected by the different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	1	0.88	0.31	0.57	64.77
	2	0.88	0.32	0.56	63.64
	3	1.14	0.42	0.72	63.16
	4	1.32	0.47	0.85	64.39
	Mean	1.06			63.99[a]
	S.E.±	0.11			0.36
2	1	0.89	0.30	0.59	66.29
	2	0.85	0.31	0.54	63.53
	3	1.16	0.38	0.78	67.24
	4	1.55	0.50	1.05	67.74
	Mean	1.11			66.20[b]
	S.E.±	0.16			0.94
3	1	0.94	0.36	0.59	62.77
	2	0.92	0.34	0.58	63.04
	3	1.28	0.50	0.78	60.94
	4	1.59	0.61	0.98	61.64
	Mean	1.18			62.10[a]
	S.E.±	0.16			0.49
4	1	1.02	0.36	0.66	64.71
	2	0.91	0.34	0.57	62.64
	3	1.34	0.48	0.86	64.18
	4	1.64	0.59	1.05	64.02
	Mean	1.23			63.89[a]
	S.E.±	0.16			0.44

a,b - values with different superscripts differ significantly.

Analysis of variance of crude protein digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	5.19	1.73	1.19
Rations	3	32.71	10.90	7.52*
Periods	3	3.33	1.11	0.77
Error	6	8.69	1.45	
Total	15	49.92		

* Significant at 5% level.

Table 14. Crude fibre digestibility coefficients in the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg	kg	kg	
1	1	1.41	0.71	0.70	49.66
	2	1.40	0.70	0.70	50.00
	3	1.83	0.92	0.91	49.73
	4	2.11	1.09	1.02	48.34
	Mean	1.69			49.43[a]
	S.E.±	0.17			0.37
2	1	1.38	0.70	0.68	49.28
	2	1.31	0.69	0.62	47.33
	3	1.80	0.94	0.86	47.78
	4	2.41	1.25	1.16	48.13
	Mean	1.73			48.13[a]
	S.E.±	0.25			0.42
3	1	1.45	0.52	0.93	64.14
	2	1.42	0.50	0.90	63.38
	3	1.97	0.69	1.28	64.97
	4	2.46	0.85	1.61	65.46
	Mean	1.83			64.49[b]
	S.E.±	0.25			0.46
4	1	1.53	0.54	0.99	64.71
	2	1.36	0.51	0.85	62.50
	3	2.02	0.74	1.28	63.37
	4	2.47	0.91	1.56	63.16
	Mean	1.85			63.44[b]
	S.E.±	0.25			0.46

a,b - values with different superscripts differ significantly.

Analysis of variance of crude fibre digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	2.69	0.90	1.34
Rations	3	927.32	309.11	461.36**
Periods	3	2.10	0.70	1.04
Error	6	4.03	0.67	
Total	15	936.14		

** Significant at 1% level.

Average crude fibre intakes were 1.69, 1.73, 1.83 and 1.86 kg with an average digestion coefficients of 49.43 ± 0.37, 48.13 ± 0.42, 64.49 ± 0.46 and 63.44 ± 0.46 per cent with the rations 1, 2, 3 and 4, respectively. The digestibility coefficients were significantly higher ($P < 0.01$) in rations 3 and 4 containing Ti_3-treated G'CP than rations 1 and 2 containing untreated G'CP.

4.3.6 Ether Extract Digestibility

Ether extract digestibility data are presented in Table 15. An average daily intakes of 0.25, 0.24, 0.30 and 0.29 kg and an average digestion coefficients of 83.13 ± 1.14, 84.10 ± 0.31, 83.83 ± 0.53 and 84.68 ± 0.63 per cent were recorded in the Murrah buffaloes which received rations 1, 2, 3 and 4, respectively. Ether extract digestibility coefficients recorded among the four treatment groups were not significantly different.

4.3.7 Nitrogen-free Extract Digestibility

Digestibility data of nitrogen-free extract of the four experimental rations in buffaloes are presented in Table 16. Average daily intakes were 2.90, 3.03, 3.28 and 3.27 kg with an average digestion coefficients of 58.19 ± 1.50, 61.87 ± 1.33, 66.35 ± 1.11 and 70.10 ± 0.64 per cent among the rations 1, 2, 3 and 4, respectively. Nitrogen-free extract digestibility coefficients recorded among the four treatment groups were significantly different ($P < 0.01$).

Table 15. Ether extract digestibility coefficients in the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	1	0.21	0.03	0.18	85.71
	2	0.21	0.04	0.17	80.95
	3	0.27	0.05	0.22	81.48
	4	0.32	0.05	0.27	84.38
	Mean	0.25			83.13
	S.E.±	0.03			1.14
2	1	0.19	0.03	0.16	84.21
	2	0.18	0.03	0.15	83.33
	3	0.25	0.04	0.21	84.00
	4	0.33	0.05	0.28	84.85
	Mean	0.24			84.10
	S.E.±	0.03			0.31
3	1	0.24	0.04	0.20	83.33
	2	0.23	0.04	0.19	82.61
	3	0.32	0.05	0.27	84.38
	4	0.40	0.06	0.34	85.00
	Mean	0.30			83.83
	S.E.±	0.04			0.53
4	1	0.24	0.04	0.20	83.33
	2	0.22	0.03	0.19	86.37
	3	0.32	0.05	0.27	84.38
	4	0.39	0.06	0.33	84.62
	Mean	0.29			84.68
	S.E.±	0.04			0.63

Analysis of variance of ether extract digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	4.70	1.57	0.54 NS
Rations	3	4.93	1.64	0.56
Periods	3	2.86	0.96	0.33
Error	6	17.50	2.92	
Total	15	29.99		

NS = Non significant.

Table 16. Nitrogen-free extract digestibility in the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	1	2.41	1.07	1.34	55.60
	2	2.41	1.07	1.34	55.60
	3	3.14	1.24	1.90	60.51
	4	3.62	1.41	2.21	61.05
	Mean	2.90			58.19[a]
	S.E.±	0.30			1.50
2	1	2.42	0.99	1.43	59.09
	2	2.30	0.89	1.41	61.30
	3	3.15	1.21	1.94	61.59
	4	4.23	1.46	2.77	65.48
	Mean	3.03			61.87[b]
	S.E.±	0.44			1.33
3	1	2.57	0.86	1.72	66.93
	2	2.52	0.89	1.63	64.68
	3	3.48	1.07	2.41	69.25
	4	4.37	1.55	2.82	64.53
	Mean	3.28			66.35[c]
	S.E.±	0.44			1.11
4	1	2.71	0.81	1.90	70.11
	2	2.41	0.71	1.70	70.54
	3	3.57	1.13	2.44	68.35
	4	4.37	1.25	3.12	71.40
	Mean	3.27			70.10[d]
	S.E.±	0.44			0.64

a,b,c,d - values with different superscripts differ significantly

Analysis of variance of nitrogen-free extract digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	21.93	7.31	1.73
Rations	3	329.89	109.96	25.52**
Periods	3	30.61	6.87	1.62
Error	6	26.40	4.23	
Total	15	391.83		

** Significant at 1% level.

4.3.8 Energy Digestibility

The average intake, outgo and digestibility of energy in Murrah buffaloes are presented in Table 17. An average intake of 26.74, 28.00, 30.31 and 30.89 Mcal with an average digestion coefficients of 60.54 ± 0.60, 62.66 ± 0.25, 65.54 ± 0.65 and 67.37 ± 0.28 per cent were recorded among the rations 1, 2, 3 and 4, respectively. There were significant ($P < 0.01$) differences in energy digestibility coefficients among the four experimental groups.

4.3.9 Neutral Detergent Solubles (NDS-cell contents) Digestibility

Daily average intake, outgo in faeces and digestibility of NDS of the Murrah buffaloes are given in Table 18. An average daily intake of 2.93, 3.39, 3.43 and 3.85 kg and an average digestibility of 69.96 ± 1.83, 72.09 ± 1.36, 73.90 ± 1.11 and 77.62 ± 0.36 per cent were recorded in the experimental animals receiving rations 1, 2, 3 and 4, respectively. NDS digestibility coefficients recorded among the four treatment groups were significantly different ($P < 0.01$).

4.3.10 Neutral Detergent Fibre (NDF-cell wall constituents) Digestibility

Digestibility of NDF of the four rations are presented in Table 19. An average NDF intake of 2.79, 3.58, 4.15 and 3.86 kg with an average digestion coefficients of 45.79 ± 0.33, 46.36 ± 0.18, 56.28 ± 0.58 and 54.77 ± 0.46 per cent were recorded among the Murrah buffaloes fed rations 1,2,3 and 4, respec- [illegible] coefficients recorded among the

Table 17. Average energy intake, outgo and digestibility in Murrah buffaloes as affected by the different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Percentage digested
		Mcal			
1	1	22.29	8.83	13.46	60.39
	2	22.25	9.14	13.11	58.92
	3	28.97	11.12	17.85	61.62
	4	33.43	12.96	20.47	61.23
	Mean	26.74			60.54[a]
	S.E.±	2.73			0.60
2	1	22.43	8.52	13.91	62.02
	2	21.31	7.98	13.33	62.55
	3	29.14	10.81	18.33	62.90
	4	39.11	14.40	24.71	63.18
	Mean	28.00			62.66[b]
	S.E.±	4.09			0.25
3	1	24.08	8.64	15.44	64.12
	2	23.56	7.84	15.72	66.72
	3	32.72	11.12	21.60	66.01
	4	40.88	14.18	26.70	65.31
	Mean	30.31			65.54[c]
	S.E.±	4.10			0.56
4	1	25.66	8.52	17.14	66.80
	2	23.82	7.50	15.32	67.13
	3	33.76	10.76	23.00	68.12
	4	41.30	13.46	27.85	67.43
	Mean	30.89			67.37[d]
	S.E.±	4.17			0.28

a,b,c,d - values with different superscripts differ significantly.

Analysis of variance of digestibility of energy

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	3.97	1.32	2.24
Rations	3	109.96	36.65	62.12**
Periods	3	2.19	0.73	1.24
Error	6	3.51	0.59	
Total	15	119.62		

** Significant at 1% level.

Table 18. Neutral detergent solubles (cell contents) digestibility in the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	1	2.44	0.80	1.64	67.21
	2	2.44	0.82	1.62	66.39
	3	3.18	0.85	2.33	73.27
	4	3.66	0.99	2.67	72.96
	Mean	2.93			69.96[a]
	S.E.±	0.30			1.83
2	1	2.71	0.81	1.90	70.11
	2	2.58	0.78	1.80	69.77
	3	3.52	0.97	2.55	72.44
	4	4.73	1.15	3.58	75.69
	Mean	3.39			72.00[b]
	S.E.±	0.49			1.36
3	1	2.73	0.70	2.03	74.36
	2	2.66	0.78	1.88	70.68
	3	3.70	0.90	2.80	75.68
	4	4.62	1.16	3.46	74.89
	Mean	3.43			73.90[b]
	S.E.±	0.46			1.11
4	1	3.70	0.70	2.50	78.13
	2	2.85	0.64	2.21	77.54
	3	4.21	0.93	3.28	77.91
	4	5.15	1.21	3.94	76.50
	Mean	3.85			77.52[c]
	S.E.±	0.52			0.36

a,b,c - values with different superscripts differ significantly.

Analysis of variance of cell contents digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	43.26	14.42	5.46*
Rations	3	124.16	41.38	15.68**
Periods	3	19.78	6.59	2.50
Error	6	15.81	2.64	
Total	15	203.00		

* Significant at 5% level.
** Significant at 1% level.

Table 19. Neutral detergent fibre (cell wall constituents) digestibility in the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg	kg	kg	
1	1	3.16	1.72	1.44	45.57
	2	3.15	1.68	1.47	46.67
	3	4.10	2.25	1.85	45.12
	4	4.74	2.57	2.17	45.78
	Mean	3.79			45.79[a]
	S.E.±	0.39			0.33
2	1	2.87	1.56	1.31	45.64
	2	2.72	1.60	1.22	44.85
	3	3.73	2.04	1.69	45.31
	4	5.00	2.72	2.28	45.60
	Mean	3.58			45.35[a]
	S.E.±	0.52			0.18
3	1	3.29	1.44	1.85	56.23
	2	3.22	1.36	1.87	57.89
	3	4.48	1.98	2.51	55.80
	4	5.60	2.51	3.09	55.18
	Mean	4.15			56.28[b]
	S.E.±	0.56			0.58
4	1	3.20	1.46	1.74	54.38
	2	2.84	1.27	1.57	55.28
	3	4.21	1.96	2.26	53.68
	4	5.15	2.28	2.87	55.73
	Mean	3.85			54.77[b]
	S.E.±	0.52			0.46

a,b - values with different superscripts differ significantly.

Analysis of variance of neutral detergent fibre digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	2.90	0.97	1.15
Rations	3	401.22	133.74	159.21**
Periods	3	0.28	0.09	0.11
Error	6	5.05	0.84	
Total	15	409.46		

** Significant at 1% level.

4.3.11 Hemicellulose Digestibility

The average hemicellulose digestibility data of the Murrah buffaloes are given in Table 20. An average daily hemicellulose intakes of 1.18, 0.87, 1.22 and 0.85 kg and an average digestibility coefficients of 60.77 ± 0.33, 62.13 ± 0.27, 66.67 ± 0.40 and 67.96 ± 0.50 per cent were recorded among the buffaloes fed rations 1, 2, 3 and 4, respectively. The differences in hemicellulose digestibility coefficients recorded among the four treatment groups were highly significant ($P < 0.01$).

4.3.12 Acid Detergent Fibre Digestibility (ADF)

Average ADF intake, outgo and digestibility coefficients data are presented in Table 21. An average ADF intakes of 2.61, 2.71, 2.94 and 3.00 kg with an average digestion coefficients of 38.03 ± 0.37, 39.92 ± 0.22, 51.80 ± 0.59 and 51.02 ± 0.62 per cent were recorded with the rations 1, 2, 3 and 4, respectively. Digestibility coefficients were higher ($P < 0.01$) in rations 3 and 4 containing NH_3-treated GNCP than in rations 1 and 2 containing untreated GNCP.

4.3.13 Cellulose Digestibility

Digestibility of cellulose of the four experimental rations are presented in Table 22. Daily intakes of 1.67, 1.77, 1.93 and 1.93 kg with an average digestion coefficients of 59.73 ± 0.30, 60.05 ± 0.05, 73.17 ± 0.97 and 73.35 ± 1.10 per cent

Table 20. Hemicellulose digestibility in the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg	kg	kg	
1	1	0.98	0.38	0.60	61.22
	2	0.98	0.38	0.60	61.22
	3	1.27	0.51	0.76	59.84
	4	1.48	0.58	0.90	60.81
	Mean	1.18			60.77[a]
	S.E.±	0.12			0.33
2	1	0.70	0.26	0.44	62.86
	2	0.66	0.25	0.41	62.12
	3	0.91	0.35	0.56	61.54
	4	1.21	0.46	0.75	61.98
	Mean	0.87			62.13[b]
	S.E.±	0.13			0.27
3	1	0.96	0.31	0.65	67.71
	2	0.95	0.32	0.63	66.32
	3	1.31	0.44	0.87	66.41
	4	1.64	0.56	1.08	65.85
	Mean	1.22			66.57[c]
	S.E.±	0.16			0.40
4	1	0.71	0.22	0.49	69.01
	2	0.63	0.21	0.42	66.67
	3	0.93	0.30	0.63	67.74
	4	1.14	0.36	0.78	68.42
	Mean	0.86			67.96[d]
	S.E.±	0.11			0.80

a,b,c,d - values with different superscripts differ significantly.

Analysis of variance of hemicellulose digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	4.07	1.36	3.24
Rations	3	142.88	47.63	113.40**
Periods	3	0.54	0.18	0.43
Error	6	2.49	0.42	
Total	15	142.88		

** Significant at 1% level.

Table 21. Acid detergent fibre digestibility in the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	1	2.18	1.34	0.84	38.53
	2	2.17	1.30	0.87	40.09
	3	2.83	1.74	1.09	38.52
	4	3.26	1.99	1.27	38.96
	Mean	2.61			39.03[a]
	S.E.±	0.27			0.37
2	1	2.17	1.30	0.87	39.91
	2	2.06	1.26	0.81	39.32
	3	2.82	1.69	1.13	40.07
	4	3.79	2.26	1.53	40.37
	Mean	2.71			39.92[a]
	S.E.±	0.40			0.22
3	1	2.38	1.18	1.20	51.50
	2	2.28	1.06	1.22	53.51
	3	3.17	1.54	1.63	51.42
	4	3.96	1.95	2.01	50.76
	Mean	2.94			51.80[b]
	S.E.±	0.40			0.59
4	1	2.49	1.24	1.25	50.20
	2	2.21	1.06	1.15	52.04
	3	3.28	1.65	1.63	49.70
	4	4.01	1.92	2.09	52.12
	Mean	3.00			51.02[b]
	S.E.±	0.41			0.62

a,b - values with different superscripts differ significantly.

Analysis of variance of acid detergent fibre digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	4.32	1.44	1.32
Rations	3	572.59	190.86	175.10**
Periods	3	0.27	0.09	0.08
Error	6	6.54	1.09	
Total	15	583.72		

** Significant at 1% level.

Table 22. Cellulose digestibility in the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	1	1.39	0.57	0.82	58.99
	2	1.39	0.55	0.84	60.43
	3	1.81	0.73	1.08	59.67
	4	2.09	0.84	1.25	59.81
	Mean	1.67			59.73[a]
	S.E.±	0.17			0.30
2	1	1.42	0.57	0.85	59.86
	2	1.36	0.55	0.80	59.26
	3	1.84	0.73	1.11	60.33
	4	2.47	0.97	1.50	60.73
	Mean	1.77			60.05[a]
	S.E.±	0.26			0.05
3	1	1.53	0.42	1.11	72.55
	2	1.50	0.36	1.14	76.00
	3	2.08	0.57	1.51	72.60
	4	2.60	0.74	1.86	71.54
	Mean	1.93			73.17[b]
	S.E.±	0.26			0.97
4	1	1.60	0.45	1.15	71.88
	2	1.43	0.36	1.07	74.83
	3	2.11	0.61	1.50	71.09
	4	2.58	0.63	1.96	75.58
	Mean	1.90			73.35[b]
	S.E.±	0.26			1.10

a,b - values with different superscripts differ significantly.

Analysis of variance of cellulose digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	8.30	2.87	0.96
Rations	3	715.40	238.47	79.49**
Periods	3	1.43	0.48	0.16
Error	6	18.02	3.00	
Total	15	743.45		

** Significant at 1% level.

were recorded with the rations 1, 2, 3 and 4, respectively. Digestibility coefficients were higher ($P < 0.01$) in rations 3 and 4 containing NH_3-treated GNCP than in rations 1 and 2 containing untreated GNCP.

4.3.14 Lignin Digestibility

Average lignin digestibility data are given in Table 23. Average daily lignin intakes were 0.54, 0.54, 0.62 and 0.62 kg and average lignin digestibility coefficients were 3.94 ± 1.07, 3.67 ± 0.46, 17.76 ± 0.37 and 18.33 ± 0.52 per cent among buffaloes fed rations 1, 2, 3 and 4, respectively. There was a significant difference ($P < 0.01$) in the lignin digestibility among the four rations. Ammonia treatment of GNCP significantly increased lignin digestibility.

4.3.15 Balance Studies

4.3.15.1 Nitrogen balance: Data on average intake, outgo and retention of nitrogen are given in Table 24. The average daily intakes were 168.61, 177.06, 189.44 and 196.42 g with rations 1, 2, 3 and 4, respectively. All the Murrah buffaloes were in positive nitrogen balance. The average daily positive nitrogen balances were 43.16 ± 4.41, 48.35 ± 7.49, 55.06 ± 7.63 and 64.54 ± 9.66 g among the groups fed rations 1, 2, 3 and 4, respectively. There was significant difference ($P < 0.01$) in positive nitrogen balances among the four experimental groups.

Table 23. Lignin digestibility in the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	1	0.45	0.43	0.02	4.44
	2	0.45	0.42	0.03	6.67
	3	0.59	0.58	0.01	1.69
	4	0.68	0.66	0.02	2.94
	Mean	0.54			3.94[a]
	S.E.±	0.06			1.07
2	1	0.43	0.41	0.02	4.65
	2	0.41	0.40	0.01	2.44
	3	0.56	0.54	0.02	3.57
	4	0.75	0.72	0.03	4.00
	Mean	0.54			3.67[a]
	S.E.±	0.08			0.46
3	1	0.49	0.40	0.09	18.37
	2	0.48	0.40	0.08	16.67
	3	0.67	0.55	0.12	17.91
	4	0.83	0.68	0.15	18.07
	Mean	0.62			17.76[b]
	S.E.±	0.08			0.37
4	1	0.51	0.41	0.10	19.61
	2	0.45	0.37	0.08	17.78
	3	0.69	0.56	0.13	18.84
	4	0.82	0.68	0.14	17.07
	Mean	0.62			18.33[b]
	S.E.±	0.08			0.52

a,b - values with different superscripts differ significantly.

Analysis of variance of lignin digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	4.26	1.42	0.75
Rations	3	811.48	270.49	142.36**
Periods	3	6.22	2.07	1.09
Error	6	11.38	1.90	
Total	15	833.34		

** Significant at 1% level.

Table 24. Nitrogen balance of the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output			Balance
			Faeces	Urine	Total	
		g				
1	1	140.56	49.60	54.68	104.28	+36.28
	2	140.31	51.20	53.74	104.94	+35.37
	3	182.72	67.20	68.00	135.20	+47.53
	4	210.84	75.20	82.18	157.38	+53.46
	Mean	168.61				+43.16[a]
	S.E.±	17.25				4.41
2	1	142.85	48.00	56.44	104.44	+38.41
	2	135.68	49.60	48.30	97.90	+37.78
	3	180.60	60.80	77.42	138.22	+47.38
	4	249.09	80.00	99.26	179.26	+69.83
	Mean	177.06				+48.35[ab]
	S.E.±	25.96				7.49
3	1	150.50	59.82	46.20	106.02	+44.48
	2	147.25	58.10	48.48	106.58	+40.67
	3	204.50	84.17	58.94	143.11	+61.39
	4	255.50	103.60	78.40	182.00	+73.50
	Mean	189.44				+55.06[b]
	S.E.±					7.63
4	1	163.20	57.60	49.56	107.16	+56.04
	2	145.10	54.40	46.59	100.99	+44.11
	3	214.71	76.80	69.16	145.96	+68.75
	4	262.65	94.40	78.98	173.38	+89.27
	Mean	196.42				+64.54[bc]
	S.E.±	26.55				9.66

a,b,c - values with different superscripts differ significantly.

Analysis of variance of nitrogen balance

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	2471.30	823.77	23.33**
Rations	3	1022.89	340.96	9.66*
Periods	3	48.38	16.13	0.46
Error	6	211.85	35.31	
Total	15	3754.42		

* Significant at 5% level
** Significant at 1% level.

4.3.15.2 Calcium Balance: Daily calcium intake, outgo and balance data of Murrah buffaloes are recorded in Table 25. All the experimental groups were in positive calcium balance. The average daily calcium balances recorded were 16.43 ± 0.20, 17.53 ± 0.34, 20.09 ± 0.30 and 19.74 ± 0.26 g among the treatment groups fed rations 1, 2, 3 and 4, respectively. There were significant differences ($P < 0.01$) in positive calcium balances among the four treatment groups.

4.3.15.3 Phosphorus Balance: Data pertaining to phosphorus intake, outgo and retention are given in Table 26. All the experimental groups were in positive phosphorus balance. The average daily phosphorus balances were 9.72 ± 0.24, 10.55 ± 0.28, 11.33 ± 0.06 and 11.36 ± 0.21 g among the buffaloes which received rations 1, 2, 3 and 4, respectively. The positive phosphorus balances observed among the four treatment groups were significantly different ($P < 0.01$).

The results of digestion and metabolic experiments in buffaloes are summarized in Table 27.

4.3.16 Plane of Nutrition of the Experimental Animals

Data on plane of nutrition of male Murrah buffaloes fed different experimental rations in the digestibility studies are presented in Table 28. The experimental rations contained 10.04, 10.58, 9.70 and 10.18 per cent digestible crude protein, respectively. The DCP values of the rations differ significantl

Table 25. Calcium balance of Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output			Balance
			Faeces	Urine	Total	
		g				
1	1	81.20	63.02	1.40	64.42	+16.79
	2	81.06	63.34	1.00	64.34	+16.72
	3	105.56	88.44	1.20	89.64	+15.92
	4	121.80	109.69	1.80	105.49	+16.31
	Mean	97.41				+16.43[a]
	S.E.±	9.96				0.20
2	1	75.33	56.61	1.20	57.81	+17.52
	2	71.55	53.20	1.20	54.40	+17.15
	3	97.38	78.20	1.20	79.40	+17.48
	4	131.36	112.98	1.40	114.38	+16.98
	Mean	94.03				+17.53[a]
	S.E.±	13.73				0.34
3	1	89.70	68.67	1.00	69.67	+20.03
	2	79.66	58.42	1.00	59.42	+20.24
	3	121.88	101.00	1.60	102.60	+19.29
	4	152.28	130.40	1.60	132.00	+20.28
	Mean	112.91				+20.09[b]
	S.E.±	16.28				0.31
4	1	89.60	69.57	1.00	70.57	+19.03
	2	79.66	58.42	1.00	59.42	+20.24
	3	117.88	96.73	1.20	97.90	+19.96
	4	144.20	122.87	1.60	124.47	+19.73
	Mean	107.84				+19.74[b]
	S.E.±	14.58				0.26

a,b - values with different superscripts differ significantly.

Analysis of variance of calcium balance

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	0.41	0.14	0.30
Rations	3	37.07	12.36	26.30**
Periods	3	0.55	0.18	0.38
Error	6	2.81	0.47	
Total	15	40.84		

** Significant at 1% level.

Table 26. Phosphorus balance of the Murrah buffaloes as affected by different rations

Ration	Animal No.	Intake	Output			Balance
			Faeces	Urine	Total	
		g				
1	1	40.88	30.80	0.20	31.00	+ 9.88
	2	40.81	30.44	0.35	30.79	+10.02
	3	53.41	43.94	0.20	44.14	+ 9.27
	4	61.32	61.18	0.15	51.33	+ 9.99
	Mean	49.04				+ 9.72[a]
	S.E.±	5.02				0.24
2	1	43.52	32.72	0.35	33.07	+10.45
	2	41.34	29.46	0.50	29.96	+11.38
	3	56.55	46.06	0.30	46.36	+10.19
	4	75.89	65.57	0.15	65.72	+10.17
	Mean	54.33				+10.55[b]
	S.E.±	7.92				0.28
3	1	48.16	34.72	1.60	36.32	+11.84
	2	47.12	34.64	0.50	35.14	+11.98
	3	65.44	53.16	0.20	53.36	+12.08
	4	81.76	69.64	0.30	69.94	+11.82
	Mean	60.62				+11.93[c]
	S.E.	8.20				0.06
4	1	44.80	32.36	1.10	33.46	+11.34
	2	30.83	18.76	0.30	19.06	+10.77
	3	58.24	46.64	0.60	47.24	+11.70
	4	72.10	60.24	0.15	60.51	+11.59
	Mean	51.67				+11.35[c]
	S.E.±	8.91				0.21

a,b,c - values with different superscripts differ significantly.

Analysis of variance of phosphorus balance

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	0.18	0.06	0.50
Rations	3	11.10	3.70	30.83**
Periods	3	1.35	0.45	3.75
Error	6	0.71	0.12	
Total	15	13.34		

** significant at 1% level.

Table 27. Digestibility coefficients and balances of various nutrients with Murrah buffaloes fed with complete rations containing GNCP

Nutrient	Experimental rations			
	1	2	3	4
Digestibility(%)				
Dry matter	56.33^{a}	58.31^{b}	64.25^{c}	66.15^{d}
Organic matter	57.78^{a}	59.69^{b}	65.91^{c}	67.75^{d}
Energy	60.54^{a}	62.66^{b}	65.54^{c}	67.37^{d}
Crude protein	63.99^{e}	66.20^{f}	62.10^{e}	63.89^{e}
Crude fibre	49.43^{a}	48.13^{a}	64.49^{b}	63.44^{b}
Ether extract	83.13	84.10	83.83	84.68
Nitrogen-free extract	68.19^{a}	61.87^{b}	66.35^{c}	70.10^{d}
Van Soest Components				
Neutral detergent solubles	69.96^{a}	72.00^{ab}	73.90^{b}	77.52^{c}
Neutral detergent fibre	45.79^{a}	45.36^{a}	56.28^{b}	54.77^{b}
Hemicellulose	60.77^{a}	62.13^{b}	66.57^{c}	67.96^{d}
Acid detergent fibre	39.03^{a}	39.92^{a}	51.80^{b}	51.02^{b}
Cellulose	59.73^{a}	60.05^{a}	73.17^{b}	73.35^{b}
Lignin	3.94^{a}	3.67^{a}	17.76^{b}	18.33^{b}
Balances (g/day)				
Nitrogen balance	+43.16^{e}	+48.36^{ef}	+55.06^{f}	+64.54^{fg}
N retention as % intake	25.60^{a}	27.07^{a}	30.07^{b}	33.69^{c}
N retention as % absorbed	40.03^{a}	41.31^{a}	48.52^{b}	53.06^{b}
Calcium balance	+16.43^{a}	+17.53^{a}	+20.09^{b}	+19.74^{b}
Phosphorus balance	+ 9.72^{a}	+10.55^{b}	+11.93^{c}	+11.35^{c}

a,b,c,d - values with different superscripts differ significantly ($P < 0.01$) row wise.

e,f,g - values with different superscripts differ significantly ($P < 0.05$) row wise.

28. Plane of nutrition of the experimental animals fed complete rations containing G.NCP

n	Body weight (kg)	Met. body weight ($kg^{.75}$)	DCP % in ration consumed	DCP Intake (g)	TDN % in ration consumed	TDN Intake (kg)	DM intake (kg)	DE intake (Mcal)	ME intake (Mcal)	Intake per unit metabolic body weight: DM (g)	DCP (g)	ME (Kcal)	Protei energy ratio
	279.5	68.36	10.04^{ab}	675	54.57^{a}	3.67	6.72	16.19	13.28	98.30	9.87	194.27	1:23.9
	279.5	68.36	10.58^{c}	737	55.57^{a}	3.87	6.97	17.54	14.38	101.96	10.78	210.36	1:23.8
	279.5	68.36	9.70^{a}	735	60.94^{b}	4.62	7.58	19.87	16.29	110.88	10.75	238.30	1:28.0
	279.5	68.36	10.18^{b}	784	62.36^{b}	4.80	7.70	20.81	17.06	112.64	11.47	249.56	1:26.8
1 2)	275.0	67.53	3.31	172	44.81	2.33	5.20	10.29	8.44	77.00	2.55	124.98	1:59.8

,c - values with different superscripts columnwise differ significantly ($P < 0.01$).

experimental animals were 675, 737, 735 and 784 g with rations 1, 2, 3 and 4, respectively.

The experimental rations 1, 2, 3 and 4 contained 54.57, 55.52, 60.94 and 62.36 per cent total digestible nutrients, respectively. Total digestible nutrients values of all the rations differed significantly ($P < 0.01$). The rations containing NH_3-treated GNCP are having higher TDN values. Average daily consumption of TDN was 3.67, 3.87, 4.62 and 4.80 kg among the rations 1, 2, 3 and 4, respectively.

The plane of nutrition of the Murrah buffaloes in terms of dry matter, digestible crude protein and metabolizable energy per unit metabolic body weight are given in Table 28. The estimated intakes of dry matter, digestible crude protein and metabolizable energy per unit metabolic body weight of the experimental animals ranged from 98.20 to 112.64 g, 9.87 to 11.47 g and 194.27 to 249.66 Kcal., respectively.

4.3.16.1 Protein-energy ratios of Experimental Rations: The estimated protein - energy ratios (digestible crude protein(g) and digestible energy (Kcal)) of the experimental rations are presented in Table 28. The protein : energy ratios were 1:23.99, 1:23.80, 1: 28.03 and 1:26.54 among the treatment groups 1, 2, 3 and 4, respectively.

4.4 DIGESTIBILITY AND METABOLIC STUDIES IN CROSS-BRED CALVES

Half way through the growth trial, when the animals were about 200 kg, a digestion and metabolic trial was conducted on 12 growing cross-bred calves (3 in each group of growth trial) in a completely randomized block design in order to find out the nutrient digestibility and availability of the four experimental rations.

4.4.1 Voluntary Feed Intake

An average daily dry matter intake of 5.11, 5.38, 5.47 and 5.64 kg were recorded by the experimental animals fed rations 1, 2, 3 and 4, respectively. The average total dry matter consumption per 100 kg body weight recorded in this experiment (Table 29) was 2.60, 2.65, 2.72 and 2.78 kg for animals fed rations 1, 2, 3 and 4, respectively. The dry matter consumption was higher ($P < 0.05$) among the calves fed rations containing NH_3-treated GNCP than the rations contained untreated GNCP but pelleting had no effect on dry matter consumption.

4.4.2 Dry Matter Digestibility

Dry matter digestibility coefficients of the calves are presented in Table 30. The average dry matter digestion coefficients recorded for rations 1, 2, 3 and 4 were 50.22 ± 0.34, 52.70 ± 0.31, 57.95 ± 0.62 and 59.04 ± 0.24 per cent, respectively. The differences in dry matter digestibility

Table 29. Dry matter intake in the cross-bred calves as affected by different rations

Ration	Animal No.	Weight	DM intake per day kg	DM intake/ 100 kg body weight
1	2	199	5.23	2.63
	3	192	4.93	2.57
	5	198	5.17	2.61
	Mean	196.33	5.11	2.60[a]
	S.E.±		0.09	0.02
2	7	200	5.32	2.66
	9	199	5.35	2.69
	11	210	5.48	2.61
	Mean	203.00	5.38	2.65[a]
	S.E.±		0.05	0.02
3	16	219	5.72	2.61
	17	190	5.19	2.73
	18	196	5.51	2.81
	Mean	201.67	5.47	2.72[b]
	S.E.±		0.15	0.06
4	19	213	5.88	2.76
	20	200	5.60	2.80
	23	195	5.44	2.79
	Mean	202.67	5.64	2.78[b]
	S.E.±		0.13	0.01

a,b - values with different superscripts differ significantly

Analysis of variance of DM intake/100 kg body weight

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	0.05	0.02	5.00*
Error	8	0.03	0.004	
Total	11	0.08		

* Significant at 5% level.

Table 30. Average dry matter intake, outgo and digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
			kg		
1	2	5.23	2.61	2.62	50.09
	3	4.93	2.48	2.45	49.70
	5	5.17	2.54	2.63	50.87
	Mean	5.11			50.22[a]
	S.E.±	0.09			0.34
2	7	5.32	2.52	2.80	52.63
	9	5.35	2.50	2.85	53.27
	11	5.48	2.62	2.86	52.19
	Mean	5.38			52.70[b]
	S.E.±	0.05			0.31
3	16	5.72	2.47	3.25	56.81
	17	5.19	2.13	3.06	58.36
	18	5.51	2.31	3.20	58.08
	Mean	5.47			57.95[c]
	S.E.±	0.15			0.62
4	19	5.88	2.38	3.50	59.52
	20	5.60	2.22	3.38	60.36
	23	5.44	2.18	3.26	59.93
	Mean	5.64			59.94[d]
	S.E.±	0.13			0.24

a,b,c,d - values with different superscripts differ significantly

Analysis of variance of % digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	180.70	61.07	122.13**
Error	8	3.99	0.50	
Total	11	187.19		

** Significant at 1% level.

coefficients recorded among the four treatment groups were highly significant ($P < 0.01$).

4.4.3 Organic Matter Digestibility

Average organic matter digestibility data of the cross-bred calves are given in Table 31. Average daily organic matter intakes were 4.48, 4.72, 4.72 and 4.86 kg with rations 1, 2, 3 and 4, respectively. Average organic matter digestibility coefficients were 61.32 ± 0.47, 63.98 ± 0.45, 59.07 ± 0.69 and 61.02 ± 0.28 per cent among the calves fed rations 1, 2, 3 and 4, respectively. There was a significant difference ($P < 0.01$) in organic matter digestibility among the four treatment groups. Pelleting and UL_3-treatment of GNCP increased organic matter digestibility.

4.4.4 Crude Protein Digestibility

Daily average crude protein intake, outgo in faeces and digestibility coefficients of the experimental animals are recorded in Table 32. An average crude protein intake of 0.80, 0.86, 0.85 and 0.90 kg with an average digestion coefficients of 60.79 ± 1.31, 63.55 ± 0.70, 57.82 ± 0.26 and 59.60 ± 0.58 per cent were recorded among the experimental animals fed rations 1, 2, 3 and 4, respectively. There was a significant difference ($P < 0.01$) in crude protein digestibility among the four treatment groups.

Table 31. Organic matter digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	2	4.59	2.20	2.39	52.07
	3	4.32	2.14	2.18	50.46
	5	4.53	2.20	2.33	51.43
	Mean	4.48			51.32[a]
	S.E.±	0.08			0.47
2	7	4.66	2.16	2.50	53.65
	9	4.69	2.12	2.57	54.80
	11	4.80	2.24	2.56	53.33
	Mean	4.72			53.93[b]
	S.E.±	0.04			0.45
3	16	4.93	2.07	2.86	58.01
	17	4.48	1.79	2.69	60.04
	18	4.75	1.94	2.81	59.16
	Mean	4.72			59.07[c]
	S.E.±	0.13			0.59
4	19	5.06	2.00	3.06	60.47
	20	4.82	1.86	2.96	61.41
	23	4.69	1.82	2.87	61.19
	Mean	4.86			61.02[d]
	S.E.±	0.11			0.28

a,b,c,d - values with different superscripts differ significantly.

Analysis of variance of organic matter digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	181.23	60.41	96.89**
Error	8	5.07	0.63	
Total	11	186.30		

** Significant at 1% level.

Table 32. Crude protein digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	2	0.82	0.32	0.50	60.98
	3	0.77	0.32	0.45	58.44
	6	0.81	0.30	0.51	62.96
	Mean	0.80			60.79^{b}
	S.E.±	0.02			1.31
2	7	0.85	0.32	0.53	62.35
	9	0.85	0.31	0.54	63.53
	11	0.88	0.31	0.57	64.77
	Mean	0.86			63.55^{a}
	S.E.±	0.01			0.70
3	16	0.89	0.38	0.51	57.30
	17	0.81	0.34	0.47	58.02
	18	0.86	0.36	0.50	58.13
	Mean	0.85			57.82^{a}
	S.E.±	0.02			0.26
4	19	0.94	0.37	0.57	60.64
	20	0.89	0.36	0.53	59.55
	23	0.87	0.36	0.51	58.62
	Mean	0.90			59.60^{ab}
	S.E.±	0.02			0.58

a,b,c - values with different superscripts differ significantly.

Analysis of variance of CP digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	52.14	17.38	8.87**
Error	8	15.65	1.96	
Total	11	67.79		

** significant at 1% level.

4.4.5 Crude fibre Digestibility

Daily average crude fibre intake, outgo in faeces and digestibility coefficients data are presented in Table 33. Average crude fibre intakes were 1.28, 1.34, 1.32 and 1.36 kg with an average digestion coefficients of 40.26 ± 0.51, 40.15 ± 0.64, 54.63 ± 0.93 and 54.30 ± 0.51 per cent with the rations 1, 2, 3 and 4, respectively. The digestibility coefficients were higher in rations 3 and 4 containing UL_3-treated GNCP than rations 1 and 2 containing untreated GNCP.

4.4.6 Ether Extract Digestibility

Ether extract digestibility data are presented in Table 34. An average intakes of 0.19, 0.18, 0.22 and 0.21 kg and an average digestion coefficients of 75.88 ± 1.69, 80.02 ± 1.69, 76.84 ± 0.97 and 81.24 ± 0.29 per cent were recorded among the rations 1, 2, 3 and 4, respectively. Ether extract digestibility coefficients recorded among the four treatment groups are significantly different ($P < 0.05$).

4.4.7 Nitrogen-free Extract Digestibility

Digestibility data of nitrogen-free extract of the four experimental rations are presented in Table 35. An average daily intakes were 2.30, 2.34, 2.33 and 2.39 kg with an average digestion coefficients of 52.19 ± 0.47, 56.21 ± 1.15, 60.37 ± 1.72 and 63.65 ± 1.05 per cent among the rations 1, 2, 3 and 4,

Table 38. Crude fibre digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	2	1.31	0.77	0.54	41.22
	3	1.24	0.75	0.49	39.52
	5	1.30	0.78	0.52	40.00
	Mean	1.28			40.25[a]
	S.E.±	0.02			0.51
2	7	1.32	0.78	0.54	40.91
	9	1.33	0.81	0.52	39.10
	11	1.36	0.81	0.55	40.44
	Mean	1.34			40.15[a]
	S.E.±	0.01			0.54
3	16	1.38	0.61	0.77	55.80
	17	1.25	0.59	0.66	52.80
	18	1.32	0.59	0.73	55.30
	Mean	1.32			54.63[b]
	S.E.±	0.0.04			0.93
4	19	1.41	0.63	0.78	55.32
	20	1.34	0.62	0.72	53.73
	23	1.30	0.60	0.70	53.85
	Mean	1.35			54.30[b]
	S.E.±	0.03			0.51

a,b = values with different superscripts differ significantly.

Analysis of variance of CF digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	610.93	203.64	254.55**
Error	3	10.03	1.25	
Total	11	620.96		

** Significant at 1% level.

Table 34. Ether extract digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	2	0.20	0.05	0.15	75.00
	3	0.19	0.05	0.14	73.68
	5	0.19	0.04	0.15	78.95
	Mean	0.19			75.88[a]
	S.E.±	0.003			1.59
2	7	0.18	0.04	0.14	77.78
	9	0.18	0.03	0.15	83.33
	11	0.19	0.04	0.15	78.95
	Mean	0.18			80.02[ab]
	S.E.	0.003			1.69
3	16	0.23	0.05	0.18	78.26
	17	0.20	0.05	0.15	75.00
	18	0.22	0.05	0.17	77.27
	Mean	0.22			76.84[a]
	S.E.±	0.008			0.97
4	19	0.22	0.04	0.18	81.82
	20	0.21	0.04	0.17	80.95
	22	0.21	0.04	0.17	80.95
	Mean	0.21			81.24[b]
	S.E.±	0.003			0.29

a, b - values with different superscripts differ significantly.

Analysis of variance of ether extract digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	58.33	19.44	4.07*
Error	8	38.25	4.78	
Total	11	96.58		

* Significant at 5% level.

Table 35. Nitrogen-free extract digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	2	2.26	1.06	1.20	53.10
	3	2.12	1.02	1.10	51.89
	5	2.23	1.08	1.15	51.57
	Mean	2.20			52.19[a]
	S.E.±	0.04			0.47
2	7	2.31	1.02	1.29	55.84
	9	2.33	0.97	1.36	58.37
	11	2.37	1.08	1.29	54.43
	Mean	2.34			56.21[b]
	S.E.±	0.02			1.15
3	16	2.43	1.03	1.40	57.61
	17	2.22	0.81	1.41	63.51
	18	2.35	0.94	1.41	60.00
	Mean	2.33			60.37[c]
	S.E.±	0.06			1.72
4	19	2.49	0.96	1.53	61.45
	20	2.38	0.84	1.54	64.71
	23	2.31	0.82	1.49	64.60
	Mean	2.39			63.56[c]
	S.E.±	0.05			1.05

a,b,c - values with different superscripts differ significantly.

Analysis of variance of NFE digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	220.30	73.43	17.53**
Error	8	30.54	4.19	
Total	11	250.84		

** Significant at 1% level.

respectively. Nitrogen-free extract digestibility coefficients recorded among the four treatment groups were significantly different ($P < 0.01$).

4.4.8 Energy Digestibility

The average intake, outgo and digestibility of energy among the experimental calves are presented in Table 36. An average intake of 20.34, 21.64, 21.89 and 22.62 Mcal with an average digestibility of 53.75 ± 0.43, 55.48 ± 0.58, 60.28 ± 0.38 and 62.00 ± 0.33 per cent were recorded among the rations 1, 2, 3 and 4, respectively. There were significant ($P < 0.01$) differences in energy digestibility coefficients among the four treatment groups.

4.4.9 Neutral Detergent Solubles (NDS - cell contents) Digestibility

Daily average intake, outgo in faeces and digestibility of NDS of the experimental animals are given in Table 37. An average daily intakes of 2.23, 2.62, 2.48 and 2.82 kg and an average digestion coefficients of 63.77 ± 0.37, 67.14 ± 0. 55, 67.80 ± 1.16 and 72.00 ± 0.98 per cent were recorded in the experimental calves fed rations 1, 2, 3 and 4, respectively. Neutral detergent solubles digestibility coefficients recorded among the four treatment groups were significantly different ($P < 0.01$).

Table 36. Average energy intake, outgo and digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Percentage digested
		Mcal			
1	2	20.82	9.52	11.30	54.27
	3	19.62	9.24	11.38	52.91
	5	20.58	9.45	11.13	54.08
	Mean	20.34			53.75[a]
	S.E.±	0.37			0.43
2	7	21.39	9.60	11.79	55.12
	9	21.51	9.33	12.18	56.62
	11	22.03	9.98	12.05	54.70
	Mean	21.64			56.48[b]
	S.E.±	0.20			0.58
3	16	22.88	9.26	13.62	59.53
	17	20.76	8.16	12.60	60.69
	18	22.04	8.68	13.36	60.62
	Mean	21.89			60.28[c]
	S.E.±	0.62			0.38
4	19	22.58	9.08	14.50	61.49
	20	22.46	8.56	13.90	61.89
	23	21.81	8.15	13.66	62.63
	Mean	22.62			62.00[d]
	S.E.±	0.52			0.33

a,b,c,d - values with different superscripts differ significantly.

Analysis of variance of energy digestibility

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	136.65	45.55	78.53**
Error	8	4.64	0.58	
Total	11	141.29		

** Significant at 1% level.

Table 37. Neutral detergent solubles (cell contents) digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	2	2.28	0.84	1.44	63.16
	3	2.15	0.78	1.37	63.72
	5	2.25	0.80	1.47	64.44
	Mean	2.22			63.77[a]
	S.E.±	0.04			0.37
2	7	2.59	0.85	1.74	67.18
	9	2.60	0.83	1.77	68.08
	11	2.66	0.90	1.76	66.17
	Mean	2.62			67.14[b]
	S.E.±	0.02			0.56
3	16	2.59	0.78	1.81	69.82
	17	2.35	0.76	1.59	67.66
	18	2.49	0.85	1.64	65.86
	Mean	2.48			67.80[b]
	S.E.±	0.07			1.16
4	19	2.94	0.86	2.08	70.75
	20	2.80	0.73	2.07	73.93
	23	2.72	0.78	1.94	71.32
	Mean	2.82			72.00[c]
	S.E.±	0.06			0.98

a,b,c - values with different superscripts differ significantly.

Analysis of variance of neutral detergent solubles digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	102.68	34.23	16.62**
Error	8	16.50	2.06	
Total	11	119.18		

** significant at 1% level.

4.4.10 Neutral Detergent Fibre (NDF -cell wall constituents) Digestibility

Digestibility of NDF of the four rations are presented in Table 38. An average NDF intake of 3.88, 3.77, 3.00 and 2.82 kg with an average digestion coefficients of 39.75 ± 0.47, 39.04 ± 0.13, 49.81 ± 1.90 and 47.87 ± 0.66 per cent were recorded among the experimental calves fed rations 1, 2, 3 and 4, respectively. Neutral detergent fibre digestibility coefficients recorded among the four rations were significantly different (P< 0.01).

4.4.11 Hemicellulose digestibility

The average hemicellulose digestibility data of the cross-bred calves were given in Table 39. An average daily hemicellulose intakes of 0.90, 0.67, 0.88 and 0.62 kg and an average digestibility coefficients of 52.01 ± 0.91, 52.46 ± 1.52, 61.31 ± 2.64 and 59.85 ± 0.93 per cent were recorded among the animals fed rations 1, 2, 3 and 4, respectively. The differences in hemicellulose digestibility coefficients recorded among the four treatment groups were highly significant (P< 0.01).

4.4.12 Acid Detergent Fibre Digestibility(ADF)

Average ADF intake, outgo and digestibility coefficients data are presented in Table 40. An average ADF intakes of 1.99, 2.09, 2.12 and 2.20 kg with an average digestion

Table 38. Neutral detergent fibre (cell wall constituents) digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	2	2.96	1.77	1.18	40.00
	3	2.78	1.70	1.08	38.84
	5	2.99	1.74	1.18	40.41
	Mean	2.88			39.75[a]
	S.E.±	0.05			0.47
2	7	2.73	1.67	1.06	38.83
	9	2.75	1.67	1.08	39.27
	11	2.82	1.72	1.10	39.01
	Mean	2.77			39.04[a]
	S.E.±	0.03			0.13
3	16	3.13	1.69	1.44	46.01
	17	2.84	1.37	1.47	51.76
	18	3.02	1.46	1.56	51.66
	Mean	3.00			49.81[b]
	S.E.±	0.08			1.90
4	19	2.94	1.52	1.42	48.30
	20	2.80	1.49	1.31	46.79
	23	2.72	1.40	1.32	48.53
	Mean	2.82			47.87[b]
	S.E.±	0.06			0.55

a, b = values with different superscripts differ significantly.

Analysis of variance of neutral detergent fibre digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	274.20	91.40	29.39**
Error	8	24.87	3.11	
Total	11	299.07		

** Significant at 1% level.

Table 39. Hemicellulose digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	2	0.92	0.44	0.48	52.17
	3	0.86	0.43	0.43	50.00
	5	0.91	0.42	0.49	53.85
	Mean	0.90			52.01[a]
	S.E.±	0.02			0.91
2	7	0.66	0.33	0.33	50.00
	9	0.67	0.30	0.37	55.22
	11	0.69	0.33	0.36	52.17
	Mean	0.67			52.46[a]
	S.E.±	0.01			1.52
3	16	0.91	0.40	0.51	56.04
	17	0.83	0.30	0.53	63.86
	18	0.89	0.32	0.57	64.04
	Mean	0.88			61.31[b]
	S.E.±	0.02			2.64
4	19	0.65	0.25	0.40	61.54
	20	0.62	0.25	0.37	59.68
	23	0.60	0.25	0.35	58.33
	Mean	0.62			59.85[b]
	S.E.±	0.01			0.93

a,b - values with different suporscripts differ significantly.

Analysis of variance of hemicellulose digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	212.53	70.84	8.31**
Error	8	68.12	8.52	
Total	11	280.65		

** Significant at 1% level.

Table 40. Acid detergent fibre digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	2	2.03	1.33	0.70	34.48
	3	1.92	1.27	0.65	33.85
	5	2.01	1.32	0.69	34.33
	Mean	1.99			34.22[a]
	S.E.±	0.03			0.19
2	7	2.07	1.34	0.73	35.27
	9	2.08	1.37	0.71	34.13
	11	2.13	1.39	0.74	34.74
	Mean	2.09			34.71[a]
	S.E.±	0.02			0.33
3	16	2.22	1.29	0.93	41.89
	17	2.01	1.07	0.94	46.77
	18	2.13	1.14	0.99	46.48
	Mean	2.12			45.05[b]
	S.E.±	0.06			1.58
4	19	2.29	1.27	1.02	44.54
	20	2.18	1.24	0.94	43.12
	22	2.12	1.15	0.97	45.75
	Mean	2.20			44.47[b]
	S.E.±	0.05			0.76

a, b. Means bearing different superscripts differ significantly.

Analysis of variance of acid detergent fibre digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	318.62	106.21	43.89**
Error	8	19.32	2.42	
Total	11	337.94		

** Significant at 1% level.

coefficients of 34.22 ± 0.19, 34.71 ± 0.33, 45.05 ± 1.58 and 44.47 ± 0.76 per cent were recorded with the rations 1, 2, 3 and 4, respectively. Digestibility coefficients were higher ($P < 0.01$) in rations 3 and 4 containing NH_3-treated GNCP than in rations 1 and 2 containing untreated GNCP.

4.4.13 Cellulose Digestibility

Digestibility of cellulose of the four experimental rations are presented in Table 41. Daily intakes of 1.27, 1.37, 1.39 and 1.41 kg with an average digestion coefficients of 52.49 ± 0.33, 52.20 ± 0.57, 66.16 ± 2.60 and 66.47 ± 1.42 per cent were recorded with the rations 1, 2, 3 and 4, respectively. Digestibility coefficients were higher ($P < 0.01$) in rations 3 and 4 containing NH_3-treated GNCP than in rations 1 and 2 containing untreated GNCP.

4.4.14 Lignin Digestibility

Average lignin digestibility data are given in Table 42. An average daily lignin intakes were 0.41, 0.41, 0.45 and 0.45 kg and average lignin digestibility coefficients were 3.21 ± 0.78, 4.03 ± 0.80, 7.44 ± 0.55 and 8.90 ± 1.06 per cent among animals fed rations 1, 2, 3 and 4, respectively. There was a significant difference ($P < 0.01$) in the lignin digestibility among the four rations. Ammonia treatment of GNCP significantly increased lignin digestibility.

Table 41. Cellulose digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	digested	Digestibility coefficient (%)
		kg	kg	kg	
1	2	1.30	0.62	0.68	52.31
	3	1.29	0.59	0.64	52.03
	5	1.28	0.60	0.68	53.13
	Mean	1.27			52.49[a]
	S.E.±	0.02			0.33
2	7	1.35	0.63	0.72	53.33
	9	1.36	0.66	0.70	51.47
	11	1.39	0.67	0.72	51.80
	Mean	1.37			52.20[a]
	S.E.±	0.01			0.57
3	16	1.46	0.57	0.89	60.96
	17	1.32	0.41	0.91	68.94
	18	1.40	0.44	0.96	68.57
	Mean	1.39			66.16[b]
	S.E.±	0.04			2.60
4	19	1.47	0.50	0.97	65.99
	20	1.40	0.50	0.90	64.29
	23	1.36	0.42	0.94	69.12
	Mean	1.41			66.47[b]
	S.E.±	0.03			1.42

a, b - values with different superscripts differ significantly.

Analysis of variance of cellulose digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	585.48	195.16	28.28**
Error	8	55.20	6.90	
Total	11	640.68		

** Significant at 1% level.

Table 42. Lignin digestibility in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output in faeces	Digested	Digestibility coefficient (%)
		kg			
1	2	0.42	0.40	0.02	4.76
	3	0.40	0.39	0.01	2.50
	5	0.42	0.41	0.01	2.38
	Mean	0.41			3.21[a]
	S.E.±	0.007			0.78
2	7	0.41	0.40	0.01	2.44
	9	0.41	0.39	0.02	4.88
	11	0.42	0.40	0.02	4.76
	Mean	0.41			4.03[a]
	S.E.±	0.003			0.80
3	16	0.47	0.43	0.04	8.51
	17	0.42	0.39	0.03	7.14
	18	0.45	0.42	0.03	6.67
	Mean	0.45			7.44[b]
	S.E.±	0.01			0.56
4	19	0.47	0.42	0.05	10.63
	20	0.44	0.40	0.04	9.09
	23	0.43	0.40	0.03	6.98
	Mean	0.45			8.90[b]
	S.E.±	0.01			1.06

a,b - values with different superscripts differ significantly.

Analysis of variance of lignin digestibility coefficients

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	66.30	22.10	11.11**
Error	8	15.92	1.99	
Total	11	82.22		

** Significant at 1% level.

4.4.15 Balance Studies

4.4.15.1 Nitrogen Balance: Data on average intake, outgo and retention of nitrogen are given in Table 43. The average daily intakes were 128.26, 137.81, 136.83 and 143.82 g with rations 1, 2, 3 and 4, respectively. All the experimental animals were in positive nitrogen balance. The average daily positive nitrogen balances were 45.21 ± 2.16, 51.05 ± 0.93, 54.47 ± 0.54 and 58.17 ± 0.48 g among the groups fed rations 1, 2, 3 and 4, respectively. There was significant difference ($P < 0.01$) in positive nitrogen balances among the four groups of calves.

4.4.15.2 Calcium Balance: Daily calcium intake, outgo and balance data of the experimental calves are recorded in Table 44. All the experimental groups were in positive calcium balance. The average daily calcium balances recorded were 11.08 ± 0.47, 11.26 ± 0.16, 13.31 ± 0.21 and 13.98 ± 0.13 g among the treatment groups fed rations 1, 2, 3 and 4, respectively. There were significant differences ($P < 0.01$) in positive calcium balances among the calves of four treatment groups.

4.4.15.3 Phosphorus Balance: Data pertaining to phosphorus intake, outgo and retention of phosphorus were given in Table 45. All the experimental groups were in positive phosphorus balance. The average daily phosphorus balances were 11.01 ± 0.33, 11.64 ± 0.43, 13.93 ± 0.28 and 13.69 ± 0.14 g among the animals which

Table 43. Nitrogen balance in the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output			Balance
			Faeces	Urine	Total	
		g				
1	2	131.27	51.20	34.13	85.33	+45.94
	3	123.74	51.20	31.37	82.57	+41.17
	5	129.77	48.00	33.24	81.24	+48.53
	Mean	128.26				+45.21[a]
	S.E.±	2.30				2.16
2	7	136.19	51.20	34.31	85.51	+50.68
	9	136.96	49.60	34.57	84.17	+52.79
	11	140.29	49.60	41.02	90.62	+49.67
	Mean	137.81				+51.05[b]
	S.E.±	1.26				0.92
3	16	143.00	60.80	28.79	89.59	+53.41
	17	129.75	54.40	20.17	74.57	+55.18
	18	137.75	57.60	25.34	82.94	+54.81
	Mean	136.83				+54.47[bc]
	S.E.±	3.86				0.54
4	19	149.94	59.20	33.47	92.67	+57.27
	20	142.80	57.60	26.31	83.91	+58.89
	23	138.72	57.60	22.76	80.36	+58.36
	Mean	143.82				+58.17[c]
	S.E.±	3.28				0.48

a,b,c - values with different superscripts differ significantly.

Analysis of variance of nitrogen balance

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	272.88	90.96	20.17**
Error	8	36.05	4.51	
Total	11	308.93		

** Significant at 1% level.

Table 44. Calcium balance of the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output			Balance
			faeces	Urine	Total	
		g				
1	2	75.84	62.63	1.20	63.83	+12.01
	3	71.49	59.94	1.10	61.04	+10.45
	5	74.97	62.78	1.40	64.18	+10.79
	Mean	74.10				+11.08[a]
	S.E.±	1.33				0.47
2	7	71.82	58.85	1.60	60.45	+11.37
	9	72.23	60.13	1.10	61.28	+10.95
	11	73.98	61.52	1.00	62.52	+11.46
	Mean	72.68				+11.26[a]
	S.E.±	0.66				0.16
3	16	85.23	70.22	1.30	71.52	+13.71
	17	77.33	62.79	1.50	64.29	+13.04
	18	82.10	67.73	1.20	68.93	+13.17
	Mean	81.55				+13.31[b]
	S.E.±	2.30				0.21
4	19	82.32	67.71	1.40	69.11	+13.21
	20	78.40	63.73	1.70	65.43	+12.97
	23	76.16	62.31	1.10	63.41	+12.75
	Mean	78.96				+12.98[b]
	S.E.±	1.80				0.13

a,b - values with different superscripts differ significantly

Analysis of variance of calcium balance

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	11.85	3.95	17.17**
Error	8	1.86	0.23	
Total	11	13.71		

** Significant at 1% level.

Table 45. Phosphorus balance of the cross-bred calves as affected by different rations

Ration	Animal No.	Intake	Output			Balance
			Faeces	Urine	Total	
		g				
1	2	38.18	26.96	0.15	27.11	+11.07
	3	35.09	25.32	0.25	25.57	+10.42
	6	37.74	26.00	0.20	26.20	+11.54
	Mean	37.20				+11.01[a]
	S.E.±	0.67				0.33
2	7	41.50	29.78	0.30	29.08	+12.42
	9	41.73	30.01	0.15	30.16	+11.57
	11	42.74	31.41	0.40	31.81	+10.93
	Mean	41.99				+11.64[a]
	S.E.±	0.38				0.43
3	16	45.76	30.89	0.50	31.39	+14.37
	17	41.52	27.90	0.30	28.10	+13.42
	18	44.08	29.82	0.25	30.07	+14.01
	Mean	43.79				+13.93[b]
	S.E.±	1.23				0.28
4	19	41.16	26.69	0.60	27.29	+13.87
	20	39.20	24.91	0.50	25.41	+13.79
	23	38.08	24.32	0.35	24.67	+13.41
	Mean	39.48				+13.69[b]
	S.E.±	0.90				0.14

a,b = values with different superscripts differ significantly.

Analysis of variance of phosphorus balance

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	19.23	6.41	22.10**
Error	8	2.33	0.29	
Total	11	21.56		

** Significant at 1% level.

received rations 1, 2, 3 and 4, respectively. The positive phosphorus balances observed among the four treatment groups were significantly different ($P < 0.01$).

The results of digestion and metabolic experiments in cross-bred calves are summarized in Table 46.

4.4.16 Plane of Nutrition of the Experimental Calves

Data on plane of nutrition of male cross-bred calves fed different experimental rations in the digestibility study are presented in Table 47. The experimental rations contained 9.52, 10.15, 9.02 and 9.51 per cent digestible crude protein (DCP), respectively. The DCP values of the experimental rations differ significantly ($P < 0.01$). Average DCP consumed by the experimental animals were 487, 547, 433 and 527 g with rations 1, 2, 3 and 4, respectively.

The experimental rations 1, 2, 3 and 4 contained 48.58, 50.65, 54.75 and 56.40 per cent total digestible nutrients, respectively. Total digestible nutrients values of all the rations differ significantly ($P < 0.01$). The rations containing NH_3-treated GNCP are having higher TDN values. Average daily consumption of TDN was 2.48, 2.72, 2.99 and 3.18 kg among the rations 1, 2, 3 and 4, respectively.

The plane of nutrition of the experimental calves in terms of dry matter, DCP and ME per unit metabolic body

Table 46. Digestibility coefficients and balances of various nutrients among cross-bred calves fed complete rations containing ground whole cotton plants

Nutrient	Experimental rations			
	1	2	3	4
Digestibility(%)				
Dry matter	50.22^{a}	52.70^{b}	57.95^{c}	59.94^{d}
Organic matter	51.32^{a}	53.93^{b}	59.07^{c}	61.02^{d}
Energy	53.75^{a}	55.48^{b}	60.28^{c}	62.00^{d}
Crude protein	60.79^{b}	63.55^{c}	57.82^{a}	59.60^{ab}
Crude fibre	40.26^{a}	40.15^{a}	54.63^{b}	54.30^{b}
Ether extract	75.88^{e}	80.02^{ef}	76.84^{e}	81.24^{f}
Nitrogen-free extract	52.19^{a}	56.21^{b}	60.37^{c}	63.55^{c}
Van Soest Components				
Neutral detergent solubles	62.77^{a}	67.14^{b}	67.80^{b}	72.00^{c}
Neutral detergent fibre	39.75^{a}	39.04^{a}	49.81^{b}	47.87^{b}
Hemicellulose	52.01^{a}	52.46^{a}	61.31^{b}	59.85^{b}
Acid detergent fibre	34.22^{a}	34.71^{a}	45.05^{b}	44.47^{b}
Cellulose	52.49^{a}	52.20^{a}	66.16^{b}	66.47^{b}
Lignin	3.21^{a}	4.03^{a}	7.44^{b}	8.90^{b}
Balances (g/day)				
Nitrogen balance	+45.21^{a}	+51.05^{b}	+54.47^{bc}	+58.17^{c}
Nitrogen retention as % intake	35.22^{a}	37.05^{ab}	39.89^{b}	40.50^{b}
Nitrogen retention as % absorbed	57.82^{a}	58.28^{a}	68.86^{b}	68.06^{b}
Calcium balance	+11.08^{a}	+11.26^{a}	+13.31^{b}	+12.98^{b}
Phosphorus balance	+11.01^{a}	+11.64^{a}	+13.93^{b}	+13.60^{b}

a,b,c,d - values with different superscripts row-wise differ significantly ($P < 0.01$)

e, f - values with different superscripts row-wise differ significantly ($P < 0.05$).

17. Plane of nutrition of the cross-bred calves** fed complete rations containing GNCP

Body weight (kg)	Met. body weight ($Wkg^{.75}$)	DCP		TDN		DM intake (kg)	DE intake (Mcal)	ME intake (Mcal)	Intake per unit metabolic body weight			Prot energ ratio
		% in ration consumed	Intake (g)	% in ration consumed	Intake (kg)				DM (g)	DCP (g)	ME (Kcal)	
196.33	52.44	9.52[b]	487	48.58[a]	2.48	5.11	11.27	9.24	97.44	9.29	176.20	1:23
203.00	53.78	10.15[c]	547	50.65[b]	2.72	5.38	12.01	9.85	100.04	10.17	183.15	1:21
201.67	53.52	9.02[a]	493	54.75[c]	2.99	5.47	13.19	10.82	102.20	9.21	202.17	1:26
202.67	53.71	9.51[b]	537	56.40[d]	3.18	5.64	14.02	11.50	105.01	10.00	214.11	1:26
* 200.00	53.19	8.16	457	66.07	3.70	5.60	16.48	13.51	105.28	8.59	254.00	1:36

a,b,c,d - values with different superscripts column-wise differ significantly ($P < 0.01$)

* Requirements of growing steers gaining 1000 g per day

** The growth rate of the experimental calves were 796, 878, 928 and 974 g/day with rations 1, 2, 3 and 4, respectively.

weight are given in Table 47. The estimated intakes of dry matter, DCP and ME per unit metabolic body weight ranged from 97.44 to 105.01 g, 9.29 to 10.17 g and 176.30 to 214.11 Kcal, respectively.

4.4.16.1 Protein-energy ratios of Experimental Rations: The estimated protein - energy ratios (digestible crude protein (g) and digestible energy (Kcal)) of the experimental rations are presented in Table 47. The protein : energy ratios were 1:25.14, 1:21.96, 1:26.75 and 1:26.11 among the treatment groups 1, 2, 3 and 4, respectively.

4.5 GROWTH STUDIES

The initial and final body weights of the cross-bred calves are presented in Table 48. Average daily gain (ADG) were 796, 878, 928 and 974 g in animals fed rations 1, 2, 3 and 4, respectively. Statistical analysis of data revealed a significant difference ($P < 0.01$) in ADG among the different treatment groups (Table 48). Average daily gain was higher in animals fed rations containing NH_3-treated GWCP than their corresponding mash/pellet rations containing untreated GWCP. However, pelleting of the mash ration improved the ADG with untreated GWCP. But such effects were not recorded due to ammonia treatment of GWCP.

Average DM consumption, weight gain, DM consumption per kg live weight gain and cost of feed per kg live weight

Table 48. Weight gains of cross-bred calves during experimental period (90 days)

Ration	Animal No.	Initial Wt. (kg)	Final Wt. (kg)	Weight gain (kg)	Average daily gain (g)
1	1	128	192	66	733
	2	173	244	71	789
	3	173	241	68	756
	4	191	260	69	767
	5	153	229	76	844
	6	131	211	80	889
	Mean	158.17	229.50	71.67	796.36[a]
	S.E.±	10.31	10.03	2.17	24.09
2	7	164	245	81	900
	8	157	229	72	800
	9	164	250	86	956
	10	147	227	80	889
	11	168	245	77	856
	12	147	225	78	867
	Mean	157.83	236.83	79.00	878.00[b]
	S.E.±	3.72	4.49	1.89	21.11
3	13	146	228	82	911
	14	154	243	89	989
	15	151	232	81	900
	16	188	268	80	889
	17	151	236	85	944
	18	161	245	84	933
	Mean	158.50	242.00	83.50	927.67[bc]
	S.E.±	6.23	5.82	1.34	14.82
4	19	171	256	85	944
	20	158	244	86	956
	21	148	232	84	933
	22	174	265	91	1011
	23	163	249	86	956
	24	147	241	94	1044
	Mean	158.50	246.17	87.67	974.00[c]
	S.E.±	4.72	4.96	1.61	17.79

a,b,c - values with different superscripts differ significantly.

Analysis of variance of weight gains of animals

Source of variation	d.f.	S.S.	M.S.	F
Treatments	3	1,03,969.30	36,656.43	15.64**
Error	20	46,882.70	2,344.14	
Total	23	1,50,852.00		

** Significant at 1% level.

gain are presented in Table 49. Average DM consumption and corresponding weight gain of the experimental animals during the experimental period were 533.58, 71.67; 535.33, 79.00; 537.62, 83.50 and 539.34 and 87.67 kg with rations 1, 2, 3 and 4, respectively. The average DM consumed (kg) and the average cost of feed (Rs.) per kg live weight gain of the experimental animals recorded were 7.44, 5.07; 6.78, 5.87; 6.44, 5.44 and 6.15 and 5.77 with rations 1, 2, 3 and 4, respectively. Significant differences ($P < 0.01$) were observed among the four rations treatments with respect to dry matter consumption and the cost of feed per kg live weight gain (Table 49). Dry matter consumption per kg gain was lowest with ration 4 and highest with ration 1. Both, ammoniation of GNCP as well as pelleting of mash ration decreased the DM required per kg live weight gain. The cost of feed per kg live weight gain were higher ($P < 0.01$) in rations containing NH_3-treated GNCP than in rations containing untreated GNCP (Table 49). Pelleting the mash ration significantly increased the cost of feed per kg live weight gain with ration containing NH_3-treated GNCP but not with ration containing untreated GNCP. The results of growth studies are summarised in Table 50.

4.6 RUMEN STUDIES

Rumen profiles in respect of nitrogen constituents, pH and total volatile fatty acids of the experimental rations are discussed below.

Table 49. Feed efficiency and cost of feed per kg live weight gain of cross-bred calves

Ration	Animal No.	Feed intake	DM intake kg/90 days	Weight gain	DM intake/ kg gain (kg)	Cost of feed/kg gain(Rs)
1	1	532.10	475.17	86	7.20	4.90
	2	582.80	520.44	71	7.33	4.99
	3	584.10	521.60	68	7.67	5.22
	4	567.90	507.13	69	7.35	5.01
	5	640.00	571.52	76	7.52	5.12
	6	678.20	605.63	80	7.57	5.15
	Mean	597.52	533.58	71.67	7.44[a]	5.07[a]
	S.E.±	21.50	19.20	2.17	0.07	0.05
2	7	600.90	536.24	81	6.62	5.15
	8	555.90	496.09	72	6.89	5.36
	9	653.40	583.09	86	6.78	5.27
	10	596.10	531.96	80	6.65	5.17
	11	596.20	532.05	77	6.91	5.38
	12	596.10	531.96	78	6.82	5.31
	Mean	599.17	535.23	79.00	6.78[b]	5.27[a]
	S.E.±	12.70	11.33	1.89	0.05	0.04
3	13	618.40	550.19	82	6.71	5.66
	14	650.20	578.48	89	6.50	5.49
	15	565.40	503.04	81	6.21	5.24
	16	601.60	535.24	80	6.69	5.65
	17	594.20	528.66	85	6.22	5.25
	18	595.80	530.08	84	6.31	5.33
	Mean	604.27	537.62	83.50	6.44[c]	5.44[b]
	S.E.±	11.55	10.27	1.34	0.09	0.08
4	19	578.80	513.45	85.	6.04	5.66
	20	594.30	527.20	86	6.13	5.75
	21	585.20	519.13	84	6.18	5.80
	22	616.50	546.90	91	6.01	5.64
	23	609.80	540.95	86	6.29	5.90
	24	663.30	588.41	94	6.26	5.87
	Mean	607.98	539.34	87.67	6.15[d]	5.77[c]
	S.E.±	12.51	11.09	1.61	0.05	0.04

a,b,c,d - values with different superscripts differ significantly.

Analysis of variance of dry matter intake and cost of feed per kg live weight gain

	Source of variation	d.f.	S.S.	M.S.	F
DM intake/kg live weight gain	Treatments	3	5.64	1.85	61.66*
	Error	20	0.55	0.03	
	Total	23	6.09		
Cost of feed/kg live weight gain	Treatments	3	1.60	0.53	26.50*
	Error	20	0.35	0.02	

Table 50. Average weight gains and feed efficiency of cross-bred calves

Item	Experimental rations			
	1	2	3	4
Number of animals	6	6	6	6
Experimental period days	90	90	90	90
Initial weight (kg)	158.17	157.83	158.50	158.50
Final weight (kg)	229.50	236.83	242.00	246.17
Weight gain in 90 days (kg)	71.67	79.00	83.50	87.67
Average daily gain (g)	796.36^{a}	878.00^{b}	927.67^{bc}	974.00^{c}
DM intake/animal/day (kg)	5.93	5.96	5.97	5.99
DM intake/100 kg body weight (kg)	2.58	2.51	2.47	2.43
DM intake/kg live weight gain (kg)	7.44^{a}	6.78^{b}	6.44^{c}	6.15^{d}
Cost of feed/kg live weight gain (Rs.)	5.07^{a}	5.27^{a}	5.44^{b}	5.77^{c}

a,b,c,d - values with different superscripts row-wise differ significantly ($P < 0.01$).

4.6.1 Nitrogen Fractions in the Rumen

4.6.1.1 Total nitrogen: Mean concentration of total nitrogen in the rumen fluid of buffaloes as affected by processing of feeds and time of sampling are presented in Table 51 and Appendix A. Average concentration of total nitrogen in the rumen fluid of animals fed different rations ranged from 48.17 to 109.33, 50.50 to 112.00, 57.83 to 116.50 and 59.67 to 118.17mg per cent with rations 1, 2, 3 and 4, respectively. Pelleting and NH_3-treatment of GNCP markedly increased the total nitrogen concentration in the rumen fluid at all times of sampling. Higher concentrations of total nitrogen were observed in animals fed rations containing NH_3-treated GNCP than the rations containing untreated GNCP. In both types, pellet fed animals showed higher concentration of total nitrogen than the corresponding mash fed animals.

Analysis of variance (Table 51 a) indicated that differences in the ruminal total nitrogen due to feed treatment was highly significant ($P < 0.01$). Total nitrogen concentration gave a highly significant ($P < 0.01$) response to time of sampling. Highest concentration of total nitrogen was observed at 2 hours after feeding both in pellet and mash fed animals.

4.6.1.2 TCA-insoluble protein nitrogen: TCA-insoluble protein nitrogen in the rumen fluid of buffaloes as affected by processing of feeds and time of sampling are presented in Table 52 and Appendix B. The concentration of TCA-insoluble nitrogen

Table 51. Mean* values for concentration of total nitrogen (mg/100 ml) in the rumen fluid of Murrah buffaloes as affected by different rations and time of sampling

Ration	Hours after feeding				Overall mean
	0	2	4	6	
1	48.17	109.33	91.50	76.50	81.38[a]
	S.E.± 0.39	0.38	0.50	0.36	3.28
2	50.50	112.00	92.83	79.67	83.75[b]
	S.E.± 0.36	0.35	0.30	0.33	3.27
3	57.83	116.50	102.67	85.83	90.71[c]
	S.E.± 0.30	0.36	0.38	0.46	3.19
4	59.67	118.17	105.00	88.33	92.79[d]
	S.E.± 0.33	0.39	0.39	0.22	3.19
Overall mean	54.04[a]	114.00[d]	98.00[c]	82.58[b]	
	S.E.± 0.72	0.54	0.88	0.71	

* Average of twelve readings

a,b,c,d - values with different superscripts in the same column and in the same row differ significantly.

Table 51a. Analysis of variance for total nitrogen

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	1.88	0.63	0.09
Rations	3	4291.22	1430.33	201.74**
Times	3	93886.30	31295.43	4414.02**
Animals X Rations	9	21.87	2.43	0.34
Animals X Times	9	12.70	1.41	0.20
Rations X Times	9	164.69	18.30	2.58
Animals X Rations X Times	27	36.55	1.35	0.19
Error	128	907.87	7.09	

** Significant at 1% level.

Table 52. Mean* values for concentration of TCA-insoluble protein nitrogen (mg/100 ml) in the rumen fluid of Murrah buffaloes as affected by different rations and time of sampling

Ration		Hours after feeding				Overall mean
		0	2	4	6	
1		21.83	39.92	29.92	22.42	28.52[a]
	S.E.±	0.34	0.34	0.36	0.29	1.08
2		24.33	43.00	32.17	25.50	31.25[b]
	S.E.±	0.26	0.35	0.24	0.26	1.09
3		27.25	48.25	40.17	31.00	36.67[c]
	S.E.±	0.18	0.22	0.27	0.35	1.20
4		29.25	50.33	43.25	34.08	39.23[d]
	S.E.±	0.25	0.31	0.33	0.19	1.20
Overall mean		25.67[a]	45.38[d]	36.38[c]	28.25[b]	
	S.E.±	0.43	0.62	0.82	0.68	

* Average of twelve readings

a,b,c,d - values with different superscripts in the same column and in the same row differ significantly.

Table 52a. Analysis of variance for TCA-insoluble protein nitrogen

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	0.84	0.28	0.05
Rations	3	3456.55	1152.18	219.46**
Times	3	11400.50	3800.17	723.84**
Animals X Rations	9	10.45	1.16	0.22
Animals X Times	9	2.30	0.26	0.05
Rations X Times	9	195.62	21.74	4.14**
Animals X Rations X Times	27	16.41	0.61	0.12
Error	128	671.45	5.25	

** Significant at 1% level.

ranged from 21.83 to 39.92, 34.33 to 43.00, 27.25 to 48.25 and 29.25 and 50.33 mg per cent in animals fed rations 1, 2, 3 and 4, respectively. Higher concentration of TCA-insoluble protein nitrogen were observed in animals fed rations containing NH_3-treated GNCP. Pelleting of mash rations also showed higher levels of TCA-insoluble protein nitrogen.

Effect of treatment was highly significant ($P < 0.01$) on the concentration of TCA-insoluble protein nitrogenin the rumen fluid of Murrah buffaloes (Table 52 a). The variations in TCA-insoluble protein nitrogen concentration, due to time of sampling was highly significant ($P < 0.01$). Peak concentration was found at 2 hours post-feeding in buffaloes fed rations containing untreated or NH_3-treated GNCP.

4.C.1.3 Ammonia nitrogen: Mean concentrations of ammonia nitrogen in rumen fluid of buffaloes as affected by feeding of the processed complete feeds and time of sampling are given in Table 53 and Appendix C. Average values of NH_3-nitrogen ranged from 9.60 to 37.13, 8.60 to 35.60, 11.13 to 32.27 and 10.00 to 32.00 mg per cent in buffaloes fed rations 1, 2, 3 and 4, respectively.

Feed treatments had highly significant effect ($P < 0.01$) on the concentration of ruminal ammonia nitrogen (Table 53 a). Higher concentrations of ammonia-nitrogen were found in animals fed mash rations than pelleted rations. Higher ammonia values were also found when the rations contained

Table 53. Mean* values for concentration of ammonia nitrogen (mg/100 ml) in the rumen fluid of Murrah buffaloes as affected by different rations and time of sampling

Ration		Hours after feeding				Overall mean
		0	2	4	6	
1		9.60	37.13	31.93	26.20	26.22^{d}
	S.E.±	0.17	0.21	0.21	0.14	1.51
2		8.60	35.60	30.27	25.73	25.05^{c}
	S.E.±	0.26	0.16	0.17	0.17	1.47
3		11.13	33.27	29.73	24.13	24.57^{b}
	S.E.±	0.15	0.12	0.17	0.13	1.23
4		10.00	32.00	28.07	22.67	23.18^{a}
	S.E.±	0.12	0.20	0.18	0.15	1.21
Overall mean		9.83^{a}	34.50^{d}	30.00^{c}	24.68b	
	S.E.±	0.16	0.30	0.22	0.22	

* Average of twelve readings

a,b,c,d - Values with different superscripts in the same column and in the same row differ significantly.

Table 53a. Analysis of variance for ammonia nitrogen

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	0.44	0.15	0.37
Rations	3	227.00	75.67	184.56**
Times	3	16566.55	5522.18	13468.74**
Animals X Rations	9	2.19	0.24	0.59
Animals X Times	9	2.81	0.31	0.76
Rations X Times	9	188.18	20.91	51.00**
Animals X Rations X Times	27	5.07	0.19	0.46
Error	128	52.48	0.41	

** Significant at 1% level.

untreated GNCP and urea irrespective of whether they are fed as mash or pellets as compared ammonia treated GNCP. Time of sampling had a highly significant ($P < 0.01$) effect on rumen ammonia concentration. Peak concentration of ammonia nitrogen was found at 2 hours after feeding in animals of all treatment groups.

4.6.1.4 Residual nitrogen: The values representing residual nitrogen concentration are presented in Table 54 and Appendix D. Mean values for residual nitrogen ranged from 15.19 to 20.32, 15.65 to 20.48, 16.27 to 23.89 and 16.88 to 27.14 mg per cent in animals fed rations, 1, 2, 3 and 4, respectively.

Highest concentrations of residual nitrogen were observed at 4 hours after feeding in animals of all the treatment groups. Both pelleting and NH_3-treatment of GNCP increased the residual nitrogen concentrations in rumen fluid. The feed treatment as well as time of sampling had a highly significant effect ($P < 0.01$) on the ruminal residual nitrogen concentration (Table 54 a).

4.6.1.5 Food and protozoal nitrogen: The values representing the concentration of food and protozoal nitrogen (mg/100 ml) are presented in Table 55 and Appendix E. The mean values ranged from 1.54 to 6.54, 1.92 to 7.50, 3.08 to 8.58 and 3.54 to 9.25 mg per cent in animals fed rations 1, 2, 3 and 4, respectively.

The feed treatment as well as time of sampling had a significant effect ($P < 0.01$) on the ruminal food and protozoal

Table 54. Mean* values for concentration of residual nitrogen (mg/100 ml) in the rumen fluid of Murrah buffaloes as affected by different rations and time of sampling

Ration		Hours after feeding				Overall mean
		0	2	4	6	
1		15.19	25.74	26.32	26.55	23.20[a]
	S.E.±	0.21	0.13	0.16	0.10	0.68
2		15.65	26.07	26.48	25.73	23.48[b]
	S.E.±	0.13	0.15	0.18	0.16	0.66
3		16.37	26.40	26.89	26.20	23.96[c]
	S.E.±	0.11	0.16	0.13	0.16	0.64
4		16.89	26.58	27.14	26.58	24.30[d]
	S.E.±	0.18	0.12	0.14	0.12	0.63
Overall mean		16.02[a]	26.20[c]	26.71[d]	26.01[b]	
	S.E.±	0.12	0.08	0.01	0.01	

* Average of twelve readings

a,b,c,d - values with different superscripts in the same column and in the same row differ significantly.

Table 84a. Analysis of variance for residual nitrogen

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	2.87	0.96	5.05**
Rations	3	34.46	11.49	60.47**
Times	3	3821.35	1273.78	6704.12**
Animals X Rations	9	1.98	0.22	1.16
Animals X Times	9	3.62	0.40	2.11
Rations X Times	9	3.61	0.40	2.11
Animals X Rations X Times	27	4.54	0.17	0.89
Error	128	24.35	0.19	

** Significant at 1% level.

Table 55. Mean* values for concentration of food and protozoal nitrogen (mg/100 ml) in the rumen fluid of Murrah buffaloes as affected by different rations and time of sampling

Ration		Hours after feeding				Overall mean
		0	2	4	6	
1		1.54	6.54	3.33	2.33	3.44[a]
	S.E.±	0.18	0.21	0.25	0.18	0.29
2		1.92	7.50	3.92	2.71	4.01[b]
	S.E.±	0.20	0.20	0.26	0.25	0.33
3		3.08	8.58	5.88	4.50	5.51[c]
	S.E.±	0.15	0.23	0.15	0.18	0.31
4		3.54	9.25	6.54	5.00	6.08[d]
	S.E.±	0.23	0.18	0.24	0.17	0.32
Overall mean		2.52[a]	7.97[d]	4.92[c]	3.64[b]	
	S.E.±	0.15	0.18	0.22	0.19	

* Average of twelve readings

a,b,c,d - values with different superscripts in the same column and in the same row differ significantly.

Table 55. Mean* values for concentration of food and protozoal nitrogen (mg/100 ml) in the rumen fluid of Murrah buffaloes as affected by different rations and time of sampling

Ration		Hours after feeding				Overall mean
		0	2	4	6	
1		1.54	6.54	3.33	2.33	3.44^{a}
	S.E.±	0.18	0.21	0.25	0.18	0.29
2		1.92	7.50	3.92	2.71	4.01^{b}
	S.E.±	0.20	0.20	0.26	0.26	0.33
3		3.08	8.58	5.88	4.50	5.51^{c}
	S.E.±	0.15	0.23	0.15	0.18	0.31
4		3.54	9.25	6.54	5.00	6.08^{d}
	S.E.±	0.23	0.18	0.24	0.17	0.32
Overall mean		2.52^{a}	7.97^{d}	4.92^{c}	3.64^{b}	
	S.E.±	0.15	0.18	0.22	0.19	

* Average of twelve readings

a,b,c,d - values with different superscripts in the same column and in the same row differ significantly.

Table 55a. Analysis of variance for food and protozoal nitrogen

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	0.05	0.02	0.03
Rations	3	222.01	74.00	108.82**
Times	3	796.76	265.59	390.57**
Animals X Rations	9	2.63	0.29	0.43
Animals X Times	9	4.00	0.44	0.65
Rations X Times	9	8.25	0.92	1.35
Animals X Rations X Times	27	5.45	0.20	0.29
Error	128	86.83	0.68	

** Significant at 1% level.

nitrogen (Table 55 a). Highest concentrations were observed with pelleted and NH_3-treated GNCP rations. Highest concentrations were observed at 2 hours after feeding with all the experimental rations.

4.6.2 pH of the Rumen Fluid

The values representing the pH of the rumen fluid are presented in Table 56 and Appendix F. The mean values of pH of rumen fluid ranged from 6.57 to 6.84, 6.55 to 6.76, 6.37 to 6.67 and 6.29 to 6.57 in rumen fluid of animals fed rations 1, 2, 3 and 4, respectively.

pH values showed highly significant ($P < 0.01$) differences with respect to feed treatments and time of sampling (Table 56 a) Lowest values were recorded at 2 hours after feeding, irrespective of the ration fed.

4.6.3 Total Volatile Fatty Acids

Mean TVFA concentration in the rumen fluid of buffaloes as affected by processing of feeds and time of sampling are presented in Table 57 and Appendix G. Mean values of TVFA ranged from 73.75 to 102.50, 75.83 to 104.33, 82.58 to 109.58 and 83.83 to 114.33 meq/l in animals fed rations 1, 2, 3 and 4, respectively.

Higher concentration of TVFA were observed in animals fed pelleted rations than the corresponding mash rations.

Table 56. Mean* values for pH in the rumen fluid of Murrah buffaloes as affected by different rations and time of sampling

Ration		Hours after feeding				Overall mean
		0	2	4	6	
1		6.84	6.57	6.67	6.73	6.70^{a}
	S.E.±	0.02	0.01	0.01	0.02	0.02
2		6.76	6.53	6.58	6.68	6.64^{b}
	S.E.±	0.02	0.02	0.02	0.02	0.02
3		6.67	6.37	6.47	6.56	6.51^{c}
	S.E.±	0.01	0.01	0.01	0.01	0.02
4		6.57	6.29	6.38	6.47	6.43^{d}
	S.E.±	0.01	0.02	0.02	0.02	0.02
Overall mean		6.71^{a}	6.44^{d}	6.52^{c}	6.61^{b}	
	S.E.±	0.02	0.02	0.02	0.02	

* Average of twelve readings

a,b,c,d - values with different superscripts in the same column and in the same row differ significantly.

Table 56a. Analysis of variance for pH

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	0.06	0.02	0.29
Rations	3	2.21	0.74	10.57**
Times	3	1.91	0.64	9.14**
Animals X Rations	9	0.08	0.01	0.14
Animals X Times	9	0.01	< 1	< 1
Rations X Times	9	0.02	< 1	< 1
Animals X Rations X Times	27	0.04	< 1	< 1
Error	128	8.32	0.07	

** Significant at 1% level.

Table 87. Mean* values for concentration of total volatile fatty acids (meq/l) in the rumen fluid of Murrah buffaloes as affected by different rations and time of sampling

Ration		Hours after feeding				Overall mean
		0	2	4	6	
1		78.75	102.50	91.42	81.50	87.29[a]
	S.E.±	0.45	0.29	0.38	0.31	1.58
2		75.83	104.33	92.83	83.92	89.23[b]
	S.E.±	0.32	0.38	0.24	0.23	1.55
3		82.58	109.58	97.83	89.25	94.81[c]
	S.E.±	0.36	0.29	0.27	0.35	1.48
4		83.83	114.33	103.75	92.25	98.54[d]
	S.E.±	0.37	0.33	0.30	0.41	1.69
Overall mean		79.00[a]	107.69[d]	96.46[c]	86.73[b]	
	S.E.±	0.65	0.69	0.72	0.64	

* Average of twelve readings

a,b,c,d - values with different superscripts in the same column and in the same row differ significantly.

Table 57a. Analysis of variance for total volatile fatty acids

Source of variation	d.f.	S.S.	M.S.	F
Animals	3	0.34	0.11	0.08
Rations	3	3824.18	1274.73	891.42**
Times	3	22170.09	7390.03	5667.85**
Animals X Rations	9	10.78	1.20	0.84
Animals X Times	9	7.38	0.82	0.57
Rations X Times	9	80.86	8.98	6.28**
Animals X Rations X Times	27	35.50	1.31	0.92
Error	128	182.70	1.43	

** significant at 1% level.

Higher TVFA concentration was also observed in animals fed rations containing NH_3-treated GNCP than the rations containing untreated GNCP. Analysis of variance (Table 57 a) showed highly significant ($P < 0.01$) differences between feed treatments as well as time of sampling with respect to TVFA concentration. Highest concentration of TVFA was observed at 2 hours after feeding in all the treatment groups.

CHAPTER V

Discussion and Conclusion

CHAPTER V

DISCUSSION AND CONCLUSION

Whole cotton plants, after the last picking of cotton, were dried, ground and either untreated or ammonia treated was fed as a sole source of roughage in the rations of Murrah buffaloes and growing cross-bred calves. Nutrient digestibility and utilization was assessed in digestion and metabolic experiments using a 4 X 4 latin square design in Murrah buffaloes and completely randomised design in cross-bred male calves.

5.1 EFFECT OF ANHYDROUS AMMONIA TREATMENT ON CHEMICAL COMPOSITION

The colour of the ammonia treated GWCP changed from light brown to dark brown and became less coarse and more pliable than the untreated one. Shenger et al. (1982a) observed browning of the corn stover treated with NH_3 at room temperature. Wang et al. (1964) demonstrated that NH_3 disrupts bonds that cement cell wall constituents and cross links in cell walls resulting in swelling and increased flexibility of the fibre.

The ammoniation process adopted in this study i.e., injecting required quantity of NH_3 into polythene bags containing weighed quantity of GWCP appears to be economical and more efficient due to usage of the ground material in polythene bags which provided more surface area that can come in contact

with NH_3 for absorption. Further there was less wastage of NH_3 as compared to the methods used by Sundstol et al.(1978) and Muettner et al. (1982) who injected NH_3 into stacked bales of hay covered with polythene sheet.

The proximate composition data (Table 5) indicated that the GMCP contained more fibre and protein when compared to an average quality mixed dry grass. Higher fibre level was due to the woody stems of the plants and higher protein level was due to the presence of about 25 to 30 per cent green leafy foilage at the time of harvest (Figures 1, 2 and 3). Ammoniation increased the crude protein content by 105 per cent (from 7.81 to 16.01) and there was not much difference in all other proximate principles due to ammoniation. Other investigators (Knapp et al., 1974; Garrett et al., 1979; Horton and Steacy, 1979 and Muettner et al., 1982) also observed that ammoniation significantly increased the nitrogen percentage in forages.

Van Soest analysis data (Table 5) indicated that the GMCP contained 19.22 per cent soluble cell contents (SCC) and 80.78 per cent cell wall constituents (CWC) and these data are comparable to low-grade crop residues like paddy straw and oat straw (Sen, 1978). Neutral detergent fibre, hemicellulose and lignin percentages decreased with ammoniation, but ADF and cellulose percentages were not affected. The lower NDF percentage of the ammonia treated GMCP recorded

Fig. 1. Cotton plants after last picking of cotton.

Fig. 2. Harvesting of cotton plants.

Fig. 3. Stacking of cotton plants before transhipment.

in this study was due to decrease in hemicellulose and lignin percentages. These results are in accordance with Buettner et al. (1982) with fescue hay. Decreased hemicellulose content by NH_3-treatment due to solubelization was reported by Solaiman et al. (1979), Horton (1981) and Horton et al.(1982). Streeter and Horn (1982) observed lower hemicellulose and lignin contents but not cellulose content of NH_3-treated wheat straw followed by peracetic acid treatment.

5.2 COST ECONOMICS

Pelleting of complete rations required additional power consumption than those of complete mash rations. Therefore, cost of pelleted rations containing untreated GNCP and NH_3-treated GNCP was more by Rs.8.61 and 8.11, respectively (Table 8) The additional cost of pelleting was due to cost of steam production and actual pelleting process. The cost of the rations containing NH_3-treated GNCP were higher than their corresponding mash/pellet containing untreated GNCP and this increased cost was due to ammoniation process which was about Rs.38.60 per 100 kg GNCP. The cost of complete ration was increased by Rs.14.28 and 13.78 per quintal for mash and pelleted ration respectively due to NH_3-treatment of GNCP (Table 9).

5.3 PROCESS FLOW AND BULK DENSITY

The complete mash and pelleted rations used in this investigation contained either untreated or NH_3-treated GNCP at

46 per cent level as a roughage source. The capacity of the pilot plant is 1000 kg per hour for concentrate feed either for mash or pellet production. However, estimated production capacities could not be obtained in processing complete rations used in this experiment. The production performance of the formulae processed worked out on an average 400, 400, 425 and 425 kg per hour, for the rations 1, 2, 3 and 4, respectively. These low production rates of complete feeds may be attributed to the low density of GNCP which was used at 46 per cent level as roughage source and also due to poor flow characteristics of the material due to low density and fibre characteristics i.e., more resistant with elongated particle shape and size. At all processing points i.e., grinding, mixing and pelleting, the low performance of the hammer mill, mixer and pellet mill to process complete rations recorded in this experiment may be attributed to the low bulk density of the ingredients high level of roughage used in the rations and also to the fibre characteristic of the roughage used in the study.

The total cost of processing (Table 8) of complete mash containing untreated and NH_3-treated GNCP per quintal, respectively was Rs.9.21 and 8.81 whereas for the corresponding pelleted rations, it was Rs.17.82 and 16.92, respectively. There is an increase of Rs.6.06 and 6.66 per quintal in the processing cost of complete mash rations 1 and 3, respectively as compared to the conventional concentrate mixture (Rs.3.15)

recorded by Reddy (1981) and this increase may be attributed to inclusion of low-density bulky GNCP used at 45 per cent level in the present study which in turn reflected on the production performance of hammer mill, mixer and pellet mill.

Groundnut cake and rice bran used in the experimental rations were of a higher bulk density (Table 7) as compared to the other ingredients used. However, pelleted complete rations improved in their bulk densities and were comparable to concentrates like groundnut cake and rice bran. It was also observed that the flow rate of complete mash rations in the conveying systems and other processing equipment was rather slow. This again may be attributed to the low bulk density, particle shape and size, fibre characteristic of roughage used and lack of free flowing characteristics of roughage material which was used in this study.

The bulk densities of complete pelleted rations were higher than the bulk densities of respective mash feeds (Table 7). The bulk densities of rations 2 and 4 (pelleted rations) were 57.78 and 61.62 per cent higher than the corresponding mash rations. These results indicate that the light roughage materials could be improved in their bulk density comparable to concentrates by grinding and pelleting. This in turn would help in easy handling, storage and economic transportation of complete feeds from areas of production to areas of scarcity.

5.4 DIGESTION AND METABOLIC STUDIES

5.4.1 Voluntary Intake

There was an increase in the average dry matter intake of rations containing ammoniated GNCP as compared to those containing untreated GNCP in both buffaloes and cattle (Tables 10 and 29). These results were in accordance with the reports of Herrera - Saldana et al. (1982) with corn cobs and husks. The greater intake of rations with ammoniated GNCP was probably due to the effect of ammoniation on fibre digestibility. This is in accordance with the observations of Nuettner et al. (1982) with fescue hay. Knapp et al.(1975) reported that cattle can readily consume ammoniated hay without adverse effects.

Pelleting of mash rations did not show significant improvement in dry matter intake in buffaloes and cattle. This was in accordance with the results of Horton et al. (1982). These workers also reported no effect of pelleting on dry matter consumption in steers fed complete feeds with wheat straw. However, this was contrary to the findings of Hazlett et al. (1960), Klosterman et al. (1960) and Khajuria and Mudgal (1975) who reported increased dry matter intake due to pelleting of the rations. Dry matter intakes recorded in the present study were optimum in both species and were in accordance with the recommendations of Kearl (1982) for buffaloes and cattle.

5.4.2 Dry Matter Digestibility

The differences in dry matter digestibility coefficients recorded among the four treatment groups (Tables 11 and 30) were highly significant ($P<0.01$). These data indicated that the dry matter digestibility improved significantly ($P<0.01$) both by ammoniation (7.88% in buffaloes and 7.49% in cattle) and pelletization (1.94% in buffaloes and 2.24% in cattle) of the complete rations containing 3%CP. Increased dry matter digestibility by ammoniation was reported by Oji et al. (1977), Horton (1978) and Horton and Stoney (1979) with cereal straws. Orskov et al. (1983) demonstrated that ammonia treatment of straw improved digestibility and that urea added at feeding time did not have a similar effect. Kaingi et al. (1981) recorded higher IVDMD with NH3-treated than urea + urease treated maize and wheat straws. Ammoniation was presumed to increase the dry matter digestibility through reaction with the lignin-carbohydrate complex (Knapp et al., 1974).

Increased dry matter digestibility observed with pelletization of mash rations in both species might be due to increased retention time of pellets in the rumen by reduced frequency and intensity of rumen contractions (Waran et al., 1980) and cooking effect of the ration during pelletization. Tro (1968) observed increased dry matter digestibility on pelleted feeds as compared to ground pellets. However, these results were contrary to the reports of Glaxter and Graham(1956

who reported depressed digestibility of pelleted roughage. However, Lindahl and Davis (1955), Asplin et al. (1957), Lindahl and Reynolds (1959) and Mayer et al. (1969) reported that pelleting of roughage had negligible or no effect on the digestibility of dry matter.

5.4.3 Organic Matter Digestibility

There was improved intakes of organic matter by ammoniation but not by pelletization (Tables 12 and 31). This might be due to higher dry matter intake on NH_3-treated rations. These findings are in accordance with the report of Herrera - Saldana et al. (1982) who recorded higher organic matter intake with NH_3-treated wheat straw. However, Coleman et al. (1978) reported 23 per cent increase in organic matter intake with pelleted feed among cross-bred steers.

Both NH_3-treatment of GNCP and pelleting of complete mash rations increased ($P < 0.01$) organic matter digestibility in buffaloes and cattle. Kaingi et al. (1981) reported higher IVOMD with NH_3-treated than urea + urease treated rice and wheat straw. Higher organic matter digestibility by NH_3-treatment was also reported by Oji et al. (1977) with corn stover, Herrera - Saldana et al. (1982) with wheat straw and Horton and Steacy (1979) with cereal straws. Long et al.(1965) observed higher organic matter digestibility with pelleted rations than mash rations. The present observations are in agreement with the results of aforesaid authors.

There was an increase of organic matter digestibility of mash and pelleted rations due to ammoniation of GWCP by 8.10 per cent in buffaloes and 7.43 per cent in cattle. If there were no associative effects between GWCP and other dietary components, the 8.10 and 7.43 per cent increase with ammoniation indicates an improvement of 18.0 and 16.5 per cent in the organic matter digestibility of GWCP in buffaloes and cattle, respectively. Horton et al. (1982) observed 16 per cent increase in organic matter digestibility of ammoniated wheat straw in complete feeds for steers.

5.4.4 Crude Protein Digestibility

Crude protein intakes (Tables 13 and 32) were higher among the rations containing NH_3-treated GWCP compared to the rations containing untreated GWCP and this may be attributed to the increased dry matter intake among these groups.

Ammonia treated GWCP resulted in decreased crude protein digestibility in buffaloes whereas the decrease in digestibility was significant ($P < 0.01$) in calves than the corresponding mash/pellet ration containing untreated GWCP. Pelletization improved the crude protein digestibility with untreated GWCP in both species. The higher crude protein digestibility with untreated GWCP rations might be due to rapid release of NH_3 from the urea present in them. The lower digestibility of crude protein in the rations containing NH_3-treated GWCP may be due to binding of the nitrogen via the Millard reaction

where condensation of sugar aldehydes or the oxidation of phenols (possibly lignin) with nitrogenous compound occurs. Since ammoniation increased level of intake, more fibre might have probably reached the large intestine possibly resulting in some hindgut fermentation. Similar observations were made by Morris and Mowat (1980) while feeding ammoniated corn stover to steers. This could also contribute to the reduction in crude protein digestibility with the ammoniated rations. The lower digestibility of crude protein in diets containing NH_3-treated G'CP was in accordance with the reports of Oji et al. (1977) in corn stover, Garrett et al. (1979) in rice straw and Horton et al. (1982) in pelleted ammoniated complete feeds. However, these results were contrary to the findings of Al-Rabbat and Heaney (1978 a), Horton and Steacy (1979) and Herrera-Saldana et al. (1982). Improved crude protein digestibility with pelletization especially with ration 2 indicates that the pelleting process had helped in improving the crude protein digestibility. Similar results were reported by Cowsert and Montgomery (1969), Nelson et al. (1968), Kawalkar and Patel (1978) and Reddy and Reddy (1979). However, these results are in contradiction with the findings of Weir et al. (1959) who found no effect on protein digestibility due to pelleting.

5.4.5 Crude Fibre Digestibility

There was increased intake of crude fibre among rations containing NH_3-treated G'CP as compared to the rations with

untreated GNCP (Tables 14 and 33) and this may be attributed to increased dry matter intake among these groups.

Crude fibre digestibility coefficients were significantly higher ($P < 0.01$) in rations 3 and 4 containing NH_3-treated GNCP than rations 1 and 2 containing untreated GNCP in both species indicating that ammoniation improved the digestibility of crude fibre. These findings were in agreement with the reports of Morton (1978) and Morton and Steacy (1979) in cereal straws. Processing of mash ration into pellet form did not show any significant improvement in the crude fibre digestibility in both the rations having untreated/NH_3-treated GNCP as roughage source in buffaloes as well as in calves. These results were in agreement with the findings of Lindahl and Reynolds (1969), Bhattacharya and Khan (1973) and Reddy and Reddy (1979) who reported insignificant difference in the digestibility of crude fibre due to pelleting process. However, these results are contrary with the findings of Weir et al. (1969), Alexander and Hentges, Jr. (1962), Beardsley (1964) and Montenot and Hopkins (1966) who reported decreased crude fibre digestibility due to pelleting while Long et al. (1965) observed increased crude fibre digestibility with pelleting as compared to that of ground ration.

5.4.6 Ether extract Digestibility

Ether extract intake was more in rations containing NH_3-treated GNCP than the rations containing untreated

GWCP (Tables 16 and 34) and this may be due to differences in dry matter intake.

Ether extract digestibility coefficients recorded among the four ration treatment groups were not significantly different in buffaloes indicating that neither ammoniation of GWCP nor pelleting of mash ration had any effect on digestibility of ether extract. Asplin et al. (1967) recorded insignificant differences in apparent digestibility of ether extract between pelleted and mash diets. However, pelleting increased the ether extract digestibility than their corresponding mash rations containing untreated/NH_3-treated GWCP in calves. Reddy (1981) also reported increased ether extract digestibility due to pelleting of mixed grass hay based on complete rations in cross-bred calves.

6.4.7 Nitrogen-free Extract Digestibility

Nitrogen-free extract intake data in Table 16 and 35 indicated that there was increased intake of NFE among the rations with NH_3-treated GWCP as compared to the rations with untreated GWCP and this may be attributed to increased dry matter intake among these groups.

Digestibility coefficients of NFE were higher ($P < 0.01$) in rations containing NH_3-treated GWCP than in the rations containing untreated GWCP in both the species. Borhami and Sundstol (1982) reported that NH_3-treatment increased enzyme

soluble organic matter of the straw and this might have probably reflected in higher NFE digestibility. Pelleting of mash containing untreated GNCP improved NFE digestibility in both species. Pelletization of mash containing ammoniated GNCP did not show any significant improvement in NFE digestibility in calves. However, there was a significant ($P<0.01$) increase in NFE digestibility due to pelletization of mash containing NH_3-treated GNCP among buffaloes. This is in agreement with the findings of Long et al. (1965) who recorded increased NFE digestibility for the pelleted rations. However, this finding is in contradiction to the findings of Lindahl and Reynolds (1959) and Reddy and Reddy (1979) who observed insignificant difference in the digestibility of NFE due to pelleting. Ibrahim and Ingalls (1971) reported decreased digestibility due to pelleting.

5.4.8 Energy Digestibility

Animals fed rations with NH_3-treated GNCP consumed more energy (Tables 17 and 36) than the animals fed rations with untreated GNCP and this might be due to higher intakes of dry matter in these treatment groups.

Both ammoniation of GNCP and pelleting of mash rations improved ($P<0.01$) the energy digestibility of the rations in buffaloes and cattle. This was in agreement with the findings of Oji et al. (1977) and Morris and Mowat (1980) in corn stover, Garrett et al. (1979) in rice straw,

Horton and Steacy (1979) in cereal straws and Al-Rabbat and Heaney (1978 a) and Herrera-Saldana et al. (1982) in wheat straw who observed higher energy digestibility with ammoniation. This was also in accordance with the findings of Satyanarayana (1981) who found significant difference in the digestible energy between complete mash and complete feed pellets containing 65 per cent dry mixed grass hay as roughage source. However, this finding was in contradiction with the findings of Lindahl and Davis (1956) and Meyer et al. (1969) who reported that pelleting did not affect the digestibility of energy.

5.4.9 Neutral Detergent Soluble (NDS-cell contents) Digestibility

Neutral detergent solubles data (Tables 18 and 37) indicated that there was increased intake of NDS among the rations with NH_3-treated GNCP as compared to the rations with untreated GNCP and this may be attributed to increased dry matter intake among these groups.

Neutral detergent solubles digestibility was improved ($P < 0.01$) by ammoniation of GNCP (4.37% in buffaloes and 4.45% in calves), than the corresponding mash/pellet ration. Pelleting of mash ration significantly increased ($P < 0.01$) NDS digestibility in both rations containing NH_3-treated GNCP as well as untreated GNCP (2.04%). However, the increase of NDS digestibility due to pelletization reflected more in

rations with NH_3-treated GWCP (3.62% in buffaloes and 4.20% in calves) than in ration with untreated GWCP (2.04% in buffaloes and 3.37% in calves). This might be due to more solubelization of cell contents by NH_3-treatment making them more suceptable to enzyme action (Weiss et al., 1972) or higher enzyme soluble organic matter content (Sorhami and Sundstol, 1982). Higher starch digestibility in NH_3-treated than urea treated barley straw in steers was observed by Orskov et al. (1983).

5.4.10 Neutral Detergent Fibre (NDF-cell wall constituents) Digestibility

Tables 19 and 20 indicated that there was improved intakes of NDF by ammoniation but not by pelletization. This might be due to higher dry matter intake among NH_3-treated groups.

Significantly higher ($P< 0.01$) NDF digestibility was observed with the rations containing NH_3-treated GWCP than the corresponding mash/pellet ration containing untreated GWCP. Pelleting of mash rations had no effect on NDF digestibility in both species. These results are in agreement with the reports of Knapp et al. (1975), Garrett et al. (1979), Horton et al. (1982) and Saenger et al. (1982 a) who reported higher NDF digestibility due to ammoniation of various low quality roughages. However, the results on the effect of pelleting on NDF digestibility recorded in this study was contrary to the findings of Horton et al. (1982) who reported decreased NDF digestibility by pelletization.

5.4.11 Hemicellulose Digestibility

Though the hemicellulose content of GNCP (Table 5) decreased with NH_3-treatment, the intakes were almost similar (Tables 20 and 39) with the corresponding mash/pellet ration containing untreated GNCP due to higher dry matter intake in the rations containing NH_3-treated GNCP. The lower levels of hemicellulose intake with pelleted rations was due to lesser hemicellulose content in pelleted rations (Table 6).

NH_3-treatment of GNCP improved ($P< 0.01$) hemicellulose digestibility in both species but pelleting of mash ration improved ($P< 0.01$) the hemicellulose digestibility only in buffaloes. This was in agreement with the findings of Saenger et al. (1982 a) who reported increased hemicellulose digestibility with NH_3-treatment of corn stalks than untreated without supplement or with supplement of urea or soyabean meal. The increased hemicellulose digestibility might be due to solubelization of hemicellulose due to NH_3-treatment (Morton et al., 1982) and further by heat treatment in pelletization process.

5.4.12 Acid Detergent Fibre (ADF) Digestibility

Higher intakes of ADF (Tables 21 and 40) with rations 3 and 4 containing NH_3-treated GNCP than with rations 1 and 2 containing untreated GNCP might be due to higher dry matter intake on those rations.

Acid detergent fibre digestibility coefficients were significantly higher ($P < 0.01$) with rations containing NH_3-treated GWCP (11.90% in buffaloes and 10.30% in calves) than the rations containing untreated GWCP. However, pelleting of mash ration had no effect on ADF digestibility in both the treatment groups. Higher ADF digestibility due to NH_3-treatment was in accordance with the results of Salaiman et al. (1979), Horton (1981) and Herrera-Saldana et al. (1982). Saenger et al. (1982a) who reported higher ADF digestibility by NH_3-treatment of corn stalks than untreated without supplement or with supplement of urea of soyabean meal.

5.4.13 Cellulose Digestibility

Higher cellulose intakes by the experimental animals fed rations containing NH_3-treated GWCP than the rations containing untreated GWCP (Tables 22 and 41) might be due to higher dry matter intake in these groups.

Cellulose digestibility coefficients were higher($P < 0.01$) with rations containing NH_3-treated GWCP (13.37% in buffaloes and 13.97% in calves) than the rations containing untreated GWCP but pelleting had no effect on cellulose digestibility in both species. Increased cellulose digestibility due to ammoniation recorded in this study are in accordance with the reports of Salaiman et al. (1979) in pelleted complete rations and Saenger (1982 a) in corn stalks with or without supplementation of urea or soyabean meal. Nuettner et al. (1982)

reported that infra-red spectral characteristics of the treated and untreated hays indicated that ammoniation significantly reduced ester bond absorbance in the fibre fraction of hay. These changes in infra-red absorbance properties presumably resulted from the breaking of ester bonds between lignin and structural carbohydrates might have been primarily responsible for the greater fibre digestibility of the ammoniated hay. However, the results are in contradiction to the findings of Gardon and Chesson (1983) who observed no effect of NH_3-treatment of barley straw on cellulose digestibility.

5.4.14 Lignin Digestibility

Higher lignin intake (Tables 23 and 42)in the animals fed rations containing untreated GWCP might be due to higher dry matter intake with these rations.

Lignin digestibility coefficients were low and almost comparable in rations containing untreated GWCP in both species. There was significant improvement ($P< 0.01$) in lignin digestibility due to NH_3-treatment but pelleting had no effect in buffaloes and calves. However, the improvement of lignin digestibility due to NH_3-treatment of GWCP was considerably low in calves as compared to buffaloes. These findings are in agreement with the findings of Horton et al. (1982) who observed higher lignin digestibility by ammoniation of wheat straw in steers.

5.4.15 Balance Studies

5.4.15.1 Nitrogen balance: Nitrogen retention (Tables 24 and 43) was more ($P < 0.01$) in ration 3 than in ration 1 and in ration 4 than in ration 2 in both species indicating that retention was more in the rations with NH_3-treated GWCP than in the corresponding mash/pellet rations. Pelletization had no effect on nitrogen retention within each group except in calves with untreated GWCP ration (Tables 24 and 43). Nitrogen retention as per cent intake was higher by 5.04 units in buffaloes and 4.06 units in calves with NH_3-treated GWCP than in rations with untreated GWCP. Though the apparent digestibility of crude protein was less in ration with NH_3-treated GWCP, the nitrogen retention was more indicating that more energy released due to higher digestibility of cell wall constituents in these rations which was utilized for better conversion of NH_3 into microbial proteins resulting in higher nitrogen retention. There was a trend towards increased nitrogen retention due to pelleting of mash rations though the retention was significantly higher ($P < 0.01$) only in calves on ration with untreated GWCP. This improved retention may be due to improved availability of energy due to pelleting process. Improved nitrogen retention by pelleting was reported by Meyer et al. (1959), Woods and Rhodes (1969) and Reddy and Reddy (1979). The increased positive nitrogen balances of pelleted rations as compared to mash rations may be attributed to increased protein intake and to the pelleting process.

5.4.15.2 Calcium balance: Higher (P< 0.01) calcium balances were observed with the rations containing NH_3-treated GWCP in both species and this might be due to higher intakes from these rations. Pelletization had no effect on calcium balance (Tables 25 and 44). This is in agreement with the observations of Reddy and Reddy (1979) who reported that pelleting had no effect on calcium balance. Animals of all the groups were on positive calcium balance indicating that all the rations could meet the calcium requirements of the animals.

5.4.15.3 Phosphorus balance: NH_3-treatment helped in improved positive phosphorus balance (P< 0.01) than that of untreated complete diets in both species (Tables 26 and 45). However, pelletization of mash containing untreated GWCP improved phosphorus retention in buffaloes. This might be due to higher intakes of phosphorus in these rations. Reddy (1981) reported improved phosphorus balance with pelletization.

The results of the metabolic studies with buffaloes and cross-bred calves revealed that buffaloes showed higher digestibility and utilization of various nutrients compared to calves indicating that buffaloes are superior to calves in utilizing the low quality roughages. Though the digestibility was less, calves were able to retain equal amount of nitrogen compared to buffaloes. This might be due to efficient utilization of absorbed nitrogen by the growing cross-bred calves.

The digestibility of cell wall constituents (Van Soest principles : NDF, ADF, Cellulose, Hemicellulose and Lignin) were in the same trend as that of the crude fibre digestibility of Weendy system of analysis among both the species used in these investigations. These data indicate that ammoniation of GWCP improved the digestibilities of fibre fractions when evaluated either by Van Soest Analysis or by Weendy system of analysis. However, pelleting did not show beneficial effects on the digestibilities of these fractions

5.4.16 Plane of Nutrition of the Experimental Animals

Digestible crude protein (DCP) intake was more with NH_3-treated GWCP rations than their corresponding mash/pellet ration with untreated GWCP in buffaloes (Table 28). However, DCP intake was slightly less in NH_3-treated pellets than their corresponding untreated pellets in calves (Table 47) and is a reflection of its lower CP digestibility. DCP intake was also more with pelleted ration than their corresponding mash rations in both species. Higher intakes of DCP might be due to higher intakes of dry matter from these rations which in turn might be due to the effect of processing of roughage based complete rations. Digestible crude protein content was highest ($P< 0.01$) with ration 2 and lowest with ration 3 with no difference between rations 1 and 4. This may be due to differences in their digestibilities. All the rations were having higher DCP level and the animals in all the treatment groups showed higher DCP intake than the recommended levels of Kearl (1982)

with regards to buffaloes and cattle. This may be attributed ad libitum feeding of the rations.

Total digestible nutrients (TDN) intake was more with rations containing NH_3-treated GNCP and also in pelleted rations in both species (Tables 28 and 47). This might be due to differences in their dry matter intake which in turn was due to improved palatability of the NH_3-treatment and processing as compared to mash rations. Higher ($P < 0.01$) TDN values were observed in rations containing NH_3-treated GNCP in both species which might be due to the higher intakes of dry matter and higher digestibility of cell wall constituents. Pelleting did not show any significant difference in TDN values though there was slightly increasing trend in both the treated and untreated diets in buffaloes but there was a significant effect in cross-bred calves.

Digestible and metabolizable energy values of NH_3-treated GNCP rations and pelleted rations were higher than their corresponding rations containing untreated GNCP or mash rations in buffaloes and calves. Results of this study revealed that NH_3-treatment of GNCP and pelleting of complete rations containing crop residues and agro-industrial by-products helped in increased dry matter intake when compared to mash rations which in turn resulted in corresponding increase in the intake of various nutrients. The intake per unit metabolic body weight for dry matter, DCP and ME were higher in the animals

fed rations containing NH_3-treated GWCP and in pelleted rations than those receiving mash rations in buffaloes. However, the DCP intake per unit metabolic body weight was slightly lower in ammoniated rations than their corresponding mash/pellet rations containing untreated GWCP. The protein : energy values were narrow in the rations with untreated GWCP than their corresponding mash/pelleted rations containing NH_3-treated GWCP. These findings may be attributed for improved energy intake and digestibility due to ammoniation process. The protein energy ratios were narrower on all rations than suggested by Kearl (1982) in both species of animals and this may be due to *ad libitum* feeding and these data also indicate that these complete feeds could be utilised for production purposes.

6.5 Growth and Feed Efficiency:

The average daily gain of cross-bred calves on the experimental rations are presented in Table 48. NH_3-treatment of GWCP and pelleting the mash rations slightly increased the average daily dry matter consumption. The higher intakes might be due to improved palatability of the rations due to ammonia treatment and steam pelleting. Garrett *et al.* (1974), Peterson *et al.* (1981), Horton *et al.* (1982) and Nelson *et al.* (1982) reported higher DM intake by NH_3-treatment of different forages. Haslett *et al.* (1960), Klostermann *et al.* (1960) and Khajuria and Mudgal (1975) reported similar trend in dry matter intake due to pelleting.

Average daily gains were 796, 878, 929 and 974 g in animals fed rations 1, 2, 3 and 4, respectively. The ADG was higher ($P < 0.01$) due to NH_3-treatment of GWCP than their corresponding mash/pellet rations containing untreated GWCP. Pelleting improved the ADG in the rations containing untreated GWCP but not in the ration containing NH_3-treated GWCP. However, there was a trend towards improved ADG due to pelleting of NH_3-treated GWCP. Increased weight gains recorded in the animals receiving NH_3-treated diets and pelleted diets indicate better utilization of various nutrients due to ammoniation and steam pelleting of the rations. These results are in agreement with the reports of Horton et al. (1982) who observed increased weight gains by NH_3-treatment and pelletization of wheat straw based complete feeds with steers. The increased weight gains due to NH_3-treatment might be due to increased cellulose digestibility and higher DM intake (Garrett et al., 1974) and considerably higher productive energy content (Al-Rabbat and Heaney, 1978 a) in these rations. NH_3-treatment of GWCP improved growth rates by 13.52 per cent. Similar increase in growth rates of 35 per cent in rice straw (Garrett et al., 1974), 86 per cent in wheat straw (Al-Rabbat and Heaney, 1978 a) and 36 per cent in wheat straw based complete rations (Horton et al., 1982) were observed. The low percentage increase in ADG (13.52) recorded in this study as compared to the results reported by other workers (35 to 86%) may be attributed to the woody

material used in this study which is more resistant than the straws. Cate et al. (1954) observed increased ADG and feed consumption with pelleted rations. The growth rates recorded in this study among cross-bred calves were higher as compared to the results reported by Ali and Reddy (1978), Reddy and Reddy (1978), Ahmed and Reddy (1979), Singh and Arora (1980) and Reddy and Reddy (1983) among the cross-bred calves of similar age group indicating that the growth rate recorded in this study was optimum and that the CWCP based complete rations supplied the required nutrients for growth. These results indicate that the waste woody cotton plants could be utilized as roughage source in the formulation of production ration for ruminants. Pelleting of the mash rations in the present investigation recorded in increased growth rates of 7.69 per cent. Horton et al. (1982) observed 24 per cent increase in growth rate with wheat straw based complete rations with steers whereas Reddy (1981) observed 18.71 per cent increase in growth due to pelleting the mash ration containing 68 per cent mixed dry grass in cross-bred calves. However, in the present investigation, pelletization did not show any significant improvement in the utilization of ammoniated ration. Thus the results of this study indicate that both pelleting and ammoniation improved gains when used alone and there was no evidence of complementary interaction when both treatments were applied together.

Feed required per unit weight gain was lower with rations containing ammoniated GWCP than the rations containing untreated GWCP (Table 49). Pelleting further reduced the feed required per unit gain in both the rations containing untreated as well as NH_3-treated GWCP as roughage source. This indicates that the rations with NH_3-treated GWCP were utilized more effectively for growth production and that pelleting the mash further increased the utilization of the nutrients. The findings of the present study are in agreement with those of Horton et al. (1982) and Nelson et al. (1982) who reported increased feed efficiency with ammoniated feeds. Similar results of increased feed intake and growth rate on pelleted rations were reported in steers of Weir et al. (1959), Cullison (1961), Garrigus et al. (1967) and Nocek and Kesler (1980).

The increased growth rates and feed efficiency due to ammoniation and pelleting were due to better utilization of ground and compounded feeds; the micro-organisms present in the rumen could break down the small particles of cellulose more efficiently than fed untreated mash. Further, it was postulated by Esplin et al. (1957) that beneficial results from pelleting was probably due to improved palatability or from more exact control of concentrate : roughage ratio rather than from an increase in the nutritive value.

The cost of feed per kg live weight gain was more ($P<0.01$) with rations containing NH_3-treated GWCP than with rations

containing untreated GWCP (Table 49). This was due to higher cost of NH_3 used for ammoniation of GWCP. Availability of NH_3 at lower costs would yield promissing results by NH_3-treatment of crop residues like GWCP. The cost of pelleted feed per kg live weight gain did not differ significantly from the corresponding mash ration containing untreated GWCP but it differed significantly with ration containing NH_3-treated GWCP. This might be due to higher growth response due to pelletization in ration containing untreated GWCP than in ration containing NH_3-treated GWCP and also due to increased cost due to ammoniation.

The feed wastage in this study among pelleted groups was nil as compared to 2.5 per cent among mash fed groups indicating that pelleting of mash feeds would prevent wastage of feeds. These results are in agreement with the reports of Reddy (1981) who observed 2.6 per cent wastage of mash with cross-bred calves and Reddy (1983) who observed 2.8 per cent wastage of mash with sheep. Reynolds and Lindahl (1960) recorded very low refusal of ground hay with no refusal of pelleted hay when fed to sheep.

5.6 RUMEN STUDIES

5.6.1 Nitrogen Fractions in the Rumen

5.6.1.1 Total nitrogen: Both NH_3-treatment of GWCP and pelletization of mash rations improved ($P < 0.01$) the total nitrogen (TN)

concentration in the SRL (Table 51). Elloit and Topps (1964) observed that the total nitrogen concentration in the rumen fluid was positively correlated with crude protein intake. In the present study animals fed rations with NH_3-treated GNCP and pelleted rations consumed higher quantities of crude protein compared to the corresponding rations with untreated GNCP/mash rations. Since the total ruminal nitrogen represents the nitrogen derived from rumen microflora and feed residues, the higher ruminal nitrogen concentrations observed in the present study with rations containing NH_3-treated GNCP and pelleted rations is in agreement with the findings of Elloit and Topps (1964).

Decreased ammonia absorption at lower pH might be a probable factor, for higher total nitrogen concentration in the diets containing NH_3-treated GNCP. An increase in pH causes NH_4^+ ions to be converted to free NH_3 which in turn will be rapidly absorbed (Hogon, 1961 and Bloomfield et al., 1963). It is quite likely that processing of mash to pellets could have improved the availability of nitrogen for microbial protein synthesis since pelleting involves steam treatment under high pressure.

The highly significant ($P < 0.01$) effect of time of sampling on the concentration of TN and the peak concentrations at 2 hours post-feeding (Table 51 a) in all the rations are in agreement with the results of Ahuja et al. (1972), Gill and Gill (1975), Bhargava et al. (1977) and Rai and Pandey (1979).

The highest concentration of TN after feeding may be due to active degradation of protein and hydrolysis of NPN substances in the rumen and the subsequent decline in the concentration of TN may be due to changes in rumen volume through inflow of saliva.

It has been fairly well accepted that for better utilization of proteins, a source of energy to microbes and a proper balance between carbohydrates and proteins are essential (Hungate, 1966 and Waldo, 1968). The higher concentration of TN in the present investigation in animals fed rations with NH_3-treated GNCP and pelleted rations might be due to better synthesis of microbial protein. Higher digestibility of cell wall constituents (fibre) and cell contents (NFE) in rations with NH_3-treated GNCP might have contributed towards the energy required for higher microbial protein synthesis. The highest concentrations of TCA - insoluble protein nitrogen in animals fed these rations (Table 52) in the present study supports this view. In addition, differences in the rate of out flow of material from rumen might have also contributed to the higher total nitrogen concentrations in the animals fed these rations. This is in accordance with the reports of increased retention time of pellets (Baran et al., 1980) and of ammoniated straw ration (Al-Rabbat and Heaney, 1978 b) in the rumen.

5.6.1.2 TCA - insoluble protein nitrogen: In the present study, higher TCA-insoluble protein nitrogen concentrations (Table 52) were observed in animals fed rations containing

NH_3-treated GNCP and also pelleted rations. This might be due to slow release of NH_3 in these rations. The reduced rate of NH_3 production may be more or less corresponding with the carbohydrates availability and utilization resulting in more efficient conversion of NH_3 into protein. A combined effect of slow rate of outflow of digesta from rumen in pellets fed animals (Reddy, 1981) coupled with enhanced utilization of NH_3 could have resulted in better utilization of dietary NPN. The higher levels of TCA insoluble nitrogen in ammoniated and pelleted rations might also be due to higher intakes of crude protein. Thompson et al. (1967) observed increase in ruminal TCA insoluble nitrogen with pelleted rations in which urea could be hydrolysed at a slower rate and build up of ammonia. Slow release of NH_3 in the rations with NH_3-treated corn stover than the control rations containing urea was reported by Morris and Mowat (1980). The lower levels of TCA insoluble nitrogen in ration 1 might be due to rapid absorption of NH_3 and due to less quantities of readily available carbohydrates compared to other rations.

Time of sampling showed a significant effect ($P < 0.01$) on the concentration of TCA-insoluble protein nitrogen (Table 52 a). These results are in agreement with the findings of Ahuja et al. (1972), Sharma and Mudgal (1976), Bhargava et al. (1977) and Rai and Pandey (1979) who reported similar effect of time of sampling in case of buffaloes. The pattern of TCA insoluble

protein nitrogen was similar to that of TN concentration with peak concentration at 2 hours after feeding. Nolan and Leng (1972) suggested that upto 30 per cent of bacteria grown in rumen were degraded in - situ. Abde and Kandatan (1969) pointed out that upto 40 per cent of bacteria produced were consumed by protozoa. The presence of bacterio-phages in the rumen (Adams et al., 1966) and the possibility of autolysis of bacteria in the rumen (Hungate, 1966) have also been demonstrated. These factors along with the flow of digesta from rumen would determine the concentration of bacteria in rumen at any given time and thus the results of increased TCA-insoluble protein N recorded in this study among ammonia treated groups indicate improved bacterial protein synthesis in the rumen.

5.6.1.3 Ammonia nitrogen: There was a significant ($P < 0.01$) difference in rumen NH_3-N in the rumen fluid of buffaloes with respect to different rations (Table 53). Levels of NH_3-N were reduced due to ammoniation and further by pelletization. Generally, the higher ruminal PN concentration in animals fed rations containing NH_3-treated GNCP and pelleted rations should result in slightly higher concentration of other nitrogen fractions. However, in the present investigation even though the protein intake was higher in the ammoniated and pelleted rations as against non-ammoniated mash, NH_3-N concentration was lower. This might be due to either slower rate of hydrolysis of nitrogen compounds in the rumen or due to an efficient

utilization of released NH_3-N by the rumen microbes due to improved availability of readily available carbohydrates by ammoniation and pelleting process used in this study. Lowered NH_3-N levels in the rumen due to heat treatment of the feed has been reported by Chalmers et al. (1964). To some extent, increased rate of NH_3 absorption from rumen wall at lower pH of rumen liquor might have resulted in lower concentration of NH_3-N in the rumen.

In the present study, the trend of rumen NH_3-N concentration as affected by the time of sampling was similar to those reported by Elliot and Topps (1964) and Tagari et al. (1965) with peak concentration recorded at 2 hours of post-feeding followed by a gradual decrease. The increased NH_3-N concentration at 2 hours after feeding could be due to deamination of amino acids (Blackburns, 1965).

Higher concentrations of NH_3-N observed prior to feeding in rations containing NH_3-treated GWCP as against those fed rations with untreated GWCP could be due to high rate of passage of digesta in animals fed rations with untreated GWCP. The lower concentrations of NH_3-N accompanied by higher concentration of TCA insoluble nitrogen in buffaloes fed rations containing NH_3-treated GWCP indicated better microbial protein synthesis in animals fed ammoniated rations. However, no such effect was observed with pelleting the rations which is contrary to the reports of Ahrar and Schingoethe (1979) in lactating cows and Reddy (1983) in sheep with complete rations.

6.6.1.4 Residual nitrogen: Residual nitrogen concentrations were higher ($P < 0.05$) with rations containing NH_3-treated GNCP and also pelleted rations (Table 54). Type of processing showed significant effect on the ruminal residual nitrogen concentration since the concentration of residual nitrogen at any given timein the rumen depends upon the rate of breakdown of proteins (Elliot and Topps, 1964), deamination of amino acids (Hungate, 1966), activity of bacteria (Adams et al., 1966) and flow of ingesta from reticulo-rumen to rumen (Moore and King, 1968). The greater concentration of residual nitrogen in buffaloes fed pelleted rations in the present study could be due to slower rate of passage of digesta from rumen to abomasum (Krishna Mohan and Raghavan, 1974). Further, higher concentrations of total nitrogen in the rumen fluid of the animals fed ammoniated and pelleted rations could have resulted in increased residual nitrogen concentration.

As regards time after feeding, significant changes in concentrations were noted after 2 hours post-feeding. The increase in concentration at 2 hours after feeding is in agreement with those of Annison (1956). He analysed NH_3, amino and peptide nitrogen in rumen liquor of sheep, fed different diets and found that both amino nitrogen and diffusible peptide nitrogen were always present in rumen liquor and their concentrations increased 5 to 10 fold, after feeding. The decrease in residual nitrogen concentration at 6 hours post-feeding may be due to variation in the microbial activity

which is invariably influenced by substrate availability, onward passage of digesta and dilution effects of water intake. The fraction of residual nitrogen consists of both the amino and diffusible peptide nitrogen along with some soluble proteins. Since these were not partitioned in the present study, it is difficult to explain the concentrations of these components in the dietary treatments used in this study.

5.6.1.5 Food and protozoal nitrogen: Higher levels ($P < 0.05$) of food and protozoal nitrogen were observed with the rations containing NH_3-treated GNCP and pelleted rations (Table 55). Time of sampling also had a significant effect on the concentration of this fraction with peak levels at 2 hours post-feeding and declining slowly there after. This follows the same trend of total nitrogen and TCA insoluble nitrogen recorded in this investigation. The changes observed in the concentration among various dietary treatments might be due to differences in concentration of protozoa. No definite trend of food and protozoal nitrogen was observed by Prasad (1981) in buffaloes and Reddy and Raghavan (1976) in buffaloes and cattle.

5.6.2 pH of the Rumen Fluid

It is generally believed that the pH of SRL is dictated by quantity and type of VFA present in reticulo-rumen. Both, the time of sampling and different dietary treatments showed significant ($P < 0.01$) effect on pH of SRL (Table 56). The

pH values in the present study were inversely related to TVFA concentration (Table 57). Phillipson (1942) and Briggs et al. (1957) also showed a definite inverse relationship between pH and TVFA concentration of rumen fluid. Morris and Mowat (1980) observed lower pH with alkali treatment most probably due to higher TVFA levels.

5.6.3 Total Volatile Fatty Acids

The total volatile fatty acids (TVFA) concentration (Table 57) in the rumen fluid of buffaloes was highly significantly different ($P < 0.01$) among the different treatment groups. The increased TVFA in diets with NH_3-treated GNCP and pelleted rations might be due to increased availability of fermentable energy with NH_3 treatment and also pelletization. Orskov et al. (1974) observed that the concentration of VFA was significantly higher when the diets were pelleted. Wright et al. (1963) showed that when feed intake was constant, the concentration of TVFA in the rumen of lambs fed pelleted diets or crushed pellets was higher than for lambs fed long or coarsely ground hay. Thus, the higher concentrations of TVFA observed in the animals fed pelleted rations in this study are in agreement with the results reported by the afore said workers. Higher VFA levels were observed by ammoniation of corn stover(Morris and Mowat, 1980; Oji et al., 1979) and wheat straw (Horton, 1978).

NH_3-treatment improved rumen fermentation as indicated by the significantly higher TVFA concentrations. The pelleting process of complete mash feeds further improved rumen fermentation as shown by increased TVFA values when compared to complete mash diets. These results indicate that ammoniation and pelleting are complementary to each other for improving carbohydrate fermentation in the rumen.

The highly significant effect ($P < 0.01$) due to time of sampling on the concentration of TVFA was in agreement with the reports of Bhargava et al. (1977). In the present investigation peak concentrations of TVFA were observed at 2 hours after feeding. Annison (1954), Bhargava et al. (1977), Rai and Pandey (1979) and Prasad (1981) reported peak concentrations of TVFA between 2 to 4 hours after feeding.

The above studies indicated that low cost ready-made non-cereal based balanced complete feeds could be formulated and processed utilizing locally available un-conventional crop residues like whole cotton plants, agro-industrial by-products and wastes which would open up a new area for augmenting feed resources to the ruminants and this type of feeding would also help in effective utilization of nutrients by the rumen micro-organisms for efficient conversion into livestock products. The production and supply of ready-made low cost feeds would also help the marginal and small farmers, landless labour and other weaker sections of the society for economical milk and

meat production as the Government has introduced many livestock development projects to augument the economical status of the down trodden. Feeding is an important constraint for successful working in all these developmental projects where crossbred and improved strains of animals are handed over to these beneficiaries. Therefore, any effort to develop and produce commercially low-cost ready-made balanced complete feeds to these beneficiaries would go a long way in the economical uplift of the weaker sections of the society through Animal Husbandry sector. Further, work on these lines should be taken up to reduce the cost of processing by improving hammer mill and pellet mill performance and developing mechanical feeding devices at hammer mill and to develop suitable designs for proper conveying systems from hopper to conditioning chamber and from coditioning chamber to the dies of the pellet mill to suit to the fibrous low dense materials which would help in commercial production of roughage based complete feeds. Availability of NH_3 on commercial scale at low cost would further facilitate the farmers to use NH_3-treatment of crop residues on farm by which the nutritive quality of low grade crop residues could be improved considerably.

CHAPTER VI

Summary

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SUMMARY

Non-cereal based, two low cost ready-made complete rations, using untreated/NH_3-treated ground whole cotton plants (GWCP) as sole source of roughage (45%) were formulated and processed into mash and pellet forms. The whole cotton plants obtained from nearby fields, after last picking of cotton were dried, ground and half of it was treated with anhydrous ammonia (NH_3) at 3.5% level on dry matter basis at room temperature keeping calculated quantities of the ground material in polythene bags for 42 days. The rations containing untreated GWCP were supplemented with urea at 1.5% level to make all the rations isonitrogenous. The resulting four experimental rations were 1. complete feed (mash) with untreated GWCP; 2. complete feed (pellet) with untreated GWCP; 3. complete feed (mash) with NH_3-treated GWCP and 4. complete feed (pellet) with NH_3-treated GWCP.

The processing cost of complete rations, mash and pellet containing 45% untreated and NH_3-treated GWCP worked out to be Rs.9.21, 17.82, 8.81 and 16.92 per quintal, respectively. The cost of the above rations was Rs. 60.81, 69.42, 75.09 and 83.20 per quintal, respectively. Processing of pelleted feeds required more power for the production of steam and for the pelleting process. Though the capacity of the feed processing plant was one tonne per hour for conventional concentrate feeds,

the production was only 400 and 425 kg pellets per hour for rations containing untreated and NH_3-treated GWCP, respectively. The reduction in pellet production was due to coarseness and low bulk density of GWCP which was used at 45% level in the rations. Pelleting increased the density of the rations containing untreated GWCP and NH_3-treated GWCP by 57.8 and 61.6%, respectively.

Digestion and metabolic experiments were conducted on 4 permanently fistulated male Murrah buffaloes in a 4 X 4 latin square design and on 12 cross-bred male calves in a completely randomised block design (3 calves from each group of the growth experiment) to study the effect of complete rations on palatability, nutrient digestibility and balances of nitrogen, calcium and phosphorus. Complete rations were also tested in a 90-day growth trial using 24 cross-bred male calves (6 in each group) to assess the effect of these rations on growth performance, feed efficiency and cost of feed per kg live weight gain. These four complete rations were also tested on 4 fistulated Murrah buffaloes used for metabolic studies to assess various metabolites of rumen liquor viz. nitrogen fractions and total volatile fatty acids (TVFA).

Ammoniation of GWCP increased the crude protein (CP) content from 7.8 to 16.0%. Voluntary intake of dry matter (DM), organic

matter (OM) and gross energy (GE) were higher among buffaloes and calves fed rations containing NH_3-treated GWCP but pelleting did not show such effect. Digestibilities of DM, OM, and GE improved by ammoniation as well as pelletization in both species of animals. Higher CP digestibility was observed with pelleted ration containing untreated GWCP in buffaloes and calves. Ammoniation had no effect on ether extract digestibility in both species. However, pelleting increased ether extract digestibility only in calves. Crude fibre digestibility improved with ammoniation but not by pelletization in both species of animals. Nitrogen-free extract digestibility also improved with ammoniation as well as pelletization, in both species.

Neutral detergent solubles digestibility was higher in rations containing NH_3-treated GWCP than their corresponding mash/pellet ration with untreated GWCP in buffaloes as well as calves. Digestibilities of neutral detergent fibre, hemicellulose, acid detergent fibre, cellulose and lignin significantly ($P<0.01$) improved with NH_3-treatment of GWCP in both buffaloes and calves. Pelleting had no such effect on the digestibilities of these fractions in both species except for hemicellulose in buffaloes.

Nitrogen balance and nitrogen retention as % intake were higher in both species of animals on rations containing NH_3-treated GWCP than their corresponding mash/pellet ration

containing untreated GWCP. Nitrogen retention as per cent absorbed was affected by ammonia treatment of GWCP but not by pelleting the mash ration in buffaloes as well as in calves. Calcium and phosphorus balances were higher on rations containing NH_3-treated GWCP than the rations containing untreated GWCP in both species. Pelleting had no effect on calcium and phosphorus retention except for the ration containing untreated GWCP in buffaloes. All the animals were on positive nitrogen, calcium and phosphorus balances. Buffaloes showed higher utilization of nutrients than calves among the rations.

Higher DCP, TDN and DE intakes were observed in rations containing NH_3-treated GWCP than their corresponding mash/pellet ration containing untreated GWCP in both species of animals except for slight decrease in DCP intake in NH_3-treated pellets in calves indicating that the animals on the rations containing NH_3-treated GWCP were on higher plane of nutrition.

A 90-day growth study was conducted on 24 cross-bred male calves of 9-12 months age with an average weight of 158 kg with 6 calves in each group. The average daily gains were 796, 878, 928 and 974 g for rations 1, 2, 3 and 4, respectively. Dry matter intake per kg gain and cost of feed per

kg gain were 7.44, 5.07; 6.78, 5.27; 6.44, 5.44 and 6.15 and 5.77 for rations 1, 2, 3 and 4, respectively. Higher average daily gain was observed in calves fed NH_3-treated GWCP rations than their corresponding mash/pellet ration containing untreated GWCP. Improved feed efficiency was observed when GWCP was ammoniated and pelleted. The cost of feed per kg live weight gain increased with ammoniation and pelletization.

Samples of rumen liquor collected before feeding (0 hours) and at 2, 4 and 6 hours after feeding were analysed for total nitrogen, ammonia nitrogen, TCA-insoluble protein nitrogen, residual nitrogen, food and protozoal nitrogen, TVFA and pH. Both ammoniation and pelletization had significant effect on the concentrations of various nitrogen fractions, TVFA and pH values of strained rumen liquor. The concentrations of total nitrogen, TCA-insoluble nitrogen, residual nitrogen and food and protozoal nitrogen were increased with NH_3-treatment and pelletization where as a reverse trend was observed for ammonia nitrogen. Ammoniation and pelletization decreased the pH values of strained rumen liquor with a corresponding increase in TVFA concentration.

The concentrations of all nitrogen fractions and TVFA were highest at 2 hours post-feeding and then declined slowly upto 6 hours post-feeding except for residual nitrogen which

recorded peak values at 4 hours post-feeding. pH was lowest at 2 hours post-feeding and increased slowly upto 6 hours post-feeding. These results indicates that ammoniation of GWCP and pelletization of mash improved the rate of fermentation and subsequent utilization of complete feeds, with GWCP as sole source of roughage, in Murrah buffaloes.

The results of this study indicated that the ready-made balanced low-cost complete feeds either as mash or pellets could be formulated and processed utilizing abundantly available waste woody crop residue viz. GWCP as sole source of roughage in ruminant rations which could also be utilized efficiently as production ration. The study also revealed that NH_3-treatment improved the feeding value of GWCP rather than urea as NPN source and further by pelletization.

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APPENDICES

APPENDIX - A

Total nitrogen in the rumen fluid of experimental animals with different rations

Ration	Days	Animal 1				Animal 2				Animal 3				Animal 4			
		Hours after feeding															
		0	2	4	6	0	2	4	6	0	2	4	6	0	2	4	6
1	1	46	108	90	76	48	110	90	74	46	108	90	76	48	108	94	76
	2	50	110	90	78	48	110	92	76	48	110	94	78	50	110	92	78
	3	50	110	90	76	48	108	90	76	48	112	92	76	48	108	94	78
2	1	52	114	94	80	50	112	92	80	48	112	92	78	52	114	94	80
	2	50	110	92	80	52	112	92	80	50	112	94	80	52	112	94	80
	3	50	112	92	82	50	112	92	80	50	112	92	78	50	110	94	78
3	1	58	116	100	84	58	114	104	88	58	116	102	88	56	116	102	84
	2	58	116	104	86	58	116	102	86	58	116	102	86	58	116	102	88
	3	56	118	104	86	60	118	104	86	58	118	102	84	58	118	104	84
4	1	60	118	106	88	58	118	104	90	60	120	106	88	58	116	102	88
	2	58	118	104	88	60	120	106	88	60	118	106	88	60	120	106	88
	3	62	116	104	88	60	118	106	90	60	118	104	88	60	118	106	88

APPENDIX - B

TCA-insoluble nitrogen in the rumen fluid of experimental animals with different rations

Ration	Days	Animal 1				Animal 2				Animal 3				Animal 4			
		Hours after feeding															
		0	2	4	6	0	2	4	6	0	2	4	6	0	2	4	6
1	1	21	39	29	22	20	40	28	21	20	38	29	22	21	38	30	21
	2	23	40	30	24	22	42	31	23	21	40	32	22	23	40	30	23
	3	22	41	29	22	23	40	29	22	23	41	30	23	23	40	32	24
2	1	25	45	34	25	24	43	32	26	24	43	32	25	23	45	33	26
	2	24	42	32	24	25	42	32	26	23	43	32	25	25	43	33	27
	3	24	43	31	27	25	44	31	25	25	42	32	25	24	41	32	25
3	1	27	48	39	30	28	47	41	33	28	49	39	33	26	48	40	30
	2	27	48	41	30	27	49	39	31	27	48	40	32	28	47	40	31
	3	27	49	41	32	28	48	42	30	27	49	40	30	27	49	40	30
4	1	29	50	44	34	29	50	42	35	29	52	44	33	28	48	41	34
	2	28	51	42	34	29	51	44	34	30	50	45	35	29	51	44	34
	3	31	49	43	34	29	51	44	35	30	51	43	34	30	50	43	33

APPENDIX - C

Ammonia nitrogen in the rumen fluid of experimental animals on different rations

Ration	Days	Animal 1				Animal 2				Animal 3				Animal 4			
		Hours after feeding															
		0	2	4	6	0	2	4	6	0	2	4	6	0	2	4	6
1	1	8.8	36.8	31.2	26.4	10.4	37.6	32.8	26.4	9.6	37.6	32.0	26.4	9.6	36.8	32.8	26.4
	2	9.6	37.6	32.0	25.6	9.6	36.8	32.0	26.4	10.4	38.4	32.8	27.2	9.6	37.6	32.8	26.4
	3	10.4	37.6	31.2	26.4	9.6	36.0	31.2	25.6	8.8	36.8	31.2	25.6	8.8	36.0	31.2	25.6
2	1	8.8	36.0	30.4	26.4	8.0	35.2	29.6	25.6	7.2	36.2	30.4	25.6	10.4	36.0	31.2	26.4
	72	8.0	35.2	29.6	25.6	9.6	36.0	30.4	26.4	9.6	36.8	31.2	26.4	8.8	35.2	30.4	25.6
	3	8.8	36.2	29.6	25.6	8.0	35.2	30.4	25.6	8.0	36.0	29.6	24.8	8.8	36.2	30.4	24.8
3	1	11.2	32.8	29.6	24.0	11.2	32.8	29.6	24.0	10.4	32.8	29.6	24.0	10.4	32.8	28.8	24.0
	2	11.2	33.6	30.4	24.8	11.2	32.8	30.4	24.0	11.2	33.6	28.8	24.0	11.2	33.6	29.6	24.8
	3	10.4	33.6	30.4	24.0	12.0	33.6	29.6	24.8	12.0	33.6	29.6	23.2	11.2	33.6	30.4	24.0
4	1	10.4	32.0	28.0	23.2	9.6	31.2	28.0	22.4	10.4	32.8	28.8	23.2	9.6	32.2	27.2	22.4
	2	9.6	31.2	27.2	22.4	10.4	32.0	28.8	23.2	9.6	31.2	28.0	22.4	10.4	32.8	28.0	21.6
	3	9.6	32.0	28.0	22.4	10.4	32.8	28.8	23.2	10.4	32.0	27.2	22.4	9.6	32.8	28.8	23.2

APPENDIX - D

Residual Nitrogen in the rumen fluid of experimental animals on different rations

Ration	Days	Animal 1				Animal 2				Animal 3				Animal 4			
		Hours after feeding															
		0	2	4	6	0	2	4	6	0	2	4	6	0	2	4	6
1	1	15.2	25.2	25.8	25.6	15.6	26.4	26.2	25.1	15.4	26.4	27.0	25.6	14.9	25.7	25.7	25.6
	2	15.4	25.4	26.0	25.4	14.4	25.2	26.0	25.1	15.1	25.6	25.2	25.8	16.9	25.4	25.7	25.6
	3	15.6	25.4	25.8	25.6	14.4	26.0	26.8	25.4	14.2	26.2	26.8	25.4	15.2	26.0	26.8	26.4
2	1	15.2	26.0	26.6	26.6	15.0	26.8	27.4	25.4	15.8	25.8	26.6	25.4	16.1	26.0	26.8	25.1
	2	16.0	24.8	26.4	26.4	15.4	26.0	26.6	25.1	15.4	26.2	25.8	25.1	16.2	25.8	25.1	25.4
	3	15.7	26.8	26.9	26.4	15.0	26.3	25.1	25.4	16.0	26.0	26.4	25.2	16.0	26.3	27.1	25.2
3	1	16.8	26.2	26.4	26.0	15.8	25.2	27.4	26.0	16.6	26.2	26.4	26.0	16.6	26.2	27.2	25.0
	2	16.3	26.4	26.6	26.2	15.8	27.2	26.6	26.0	16.3	26.4	27.2	26.0	16.8	27.4	26.4	27.2
	3	16.1	26.4	27.1	26.0	16.5	26.4	27.4	26.7	16.0	26.4	26.4	26.3	16.8	26.4	27.6	27.0
4	1	16.6	27.0	27.0	25.8	16.4	26.8	27.0	26.6	15.6	16.2	27.2	26.8	17.4	26.8	27.1	27.1
	2	17.4	26.8	26.8	26.6	16.6	27.0	27.2	26.8	16.4	26.8	27.0	26.1	17.6	27.2	28.0	26.4
	3	17.4	26.0	27.0	26.6	17.1	26.2	27.7	26.8	17.6	26.0	26.8	26.1	16.4	26.2	26.2	27.3

APPENDIX - B

Food and Protosoal Nitrogen in the rumen fluid of experimental animals on different rations

Ration	Days	Animal 1				Animal 2				Animal 3				Animal 4			
		Hours after feeding															
		0	2	4	6	0	2	4	6	0	2	4	6	0	2	4	6
1	1	1.0	7.0	4.0	2.0	2.0	6.0	3.0	1.5	1.0	6.0	2.0	2.0	2.5	7.5	4.5	3.0
	2	2.0	7.0	2.0	3.0	2.0	6.0	3.0	1.5	1.5	6.0	4.0	3.0	0.5	7.0	2.5	3.0
	3	2.0	6.0	4.0	2.0	1.0	6.0	3.0	3.0	2.0	8.0	4.0	2.0	1.0	6.0	4.0	2.0
2	1	3.0	7.0	3.0	2.0	3.0	7.0	3.0	3.0	1.0	8.0	3.0	2.0	2.5	7.0	3.0	1.5
	2	2.0	8.0	4.0	4.0	2.0	8.0	3.0	1.5	2.0	6.0	5.0	3.5	1.0	8.0	5.5	2.0
	3	1.5	7.0	4.5	3.0	2.0	8.5	4.5	4.0	1.0	8.0	4.0	3.0	2.0	7.5	4.5	3.0
3	1	3.0	9.0	5.0	4.0	3.0	7.0	6.0	5.0	3.0	8.0	7.0	5.0	3.0	9.0	6.0	5.0
	2	3.5	8.0	6.0	5.0	4.0	9.0	6.0	5.0	3.5	8.0	6.0	4.0	2.0	8.0	6.0	5.0
	3	2.5	9.0	5.5	4.0	3.5	10.0	5.0	4.5	3.0	9.0	6.0	4.5	3.0	9.0	6.0	3.0
4	1	4.0	9.0	7.0	5.0	3.0	10.0	7.0	6.0	5.0	9.0	6.0	5.0	3.0	10.0	6.0	4.5
	2	3.0	9.0	8.0	5.0	4.0	10.0	6.0	4.0	4.0	10.0	6.0	4.5	3.0	9.0	6.0	6.0
	3	4.0	9.0	6.0	5.0	3.5	8.0	5.5	5.0	2.0	9.0	7.0	5.5	4.0	9.0	8.0	4.5

APPENDIX - F

pH of the rumen fluid of experimental animals on different rations

Ration	Days	Animal 1				Animal 2				Animal 3				Animal 4			
		Hours after feeding															
		0	2	4	6	0	2	4	6	0	2	4	6	0	2	4	6
1	1	6.8	6.6	6.6	6.7	6.9	6.6	6.7	6.8	6.9	6.6	6.6	6.8	6.7	6.5	6.6	6.6
	2	6.9	6.6	6.7	6.8	6.8	6.5	6.7	6.7	6.8	6.5	6.6	6.7	6.9	6.6	6.7	6.8
	3	6.8	6.6	6.7	6.7	6.9	6.6	6.7	6.7	6.9	6.6	6.7	6.8	6.8	6.5	6.7	6.7
2	1	6.7	6.5	6.6	6.7	6.8	6.6	6.6	6.7	6.7	6.5	6.6	6.6	6.8	6.6	6.6	6.7
	2	6.8	6.6	6.6	6.7	6.9	6.6	6.7	6.8	6.8	6.5	6.6	6.7	6.7	6.5	6.6	6.7
	3	6.7	6.5	6.5	6.6	6.7	6.5	6.5	6.6	6.8	6.6	6.6	6.7	6.7	6.4	6.5	6.6
3	1	6.6	6.3	6.4	6.5	6.6	6.3	6.4	6.5	6.7	6.4	6.5	6.6	6.7	6.4	6.5	6.6
	2	6.7	6.4	6.5	6.6	6.7	6.4	6.5	6.6	6.7	6.4	6.5	6.6	6.6	6.3	6.4	6.5
	3	6.7	6.4	6.5	6.6	6.6	6.3	6.4	6.5	6.7	6.4	6.5	6.6	6.7	6.4	6.5	6.5
4	1	6.6	6.3	6.4	6.5	6.5	6.3	6.4	6.5	6.6	6.3	6.4	6.5	6.5	6.2	6.3	6.4
	2	6.5	6.2	6.3	6.4	6.6	6.4	6.5	6.5	6.6	6.3	6.4	6.4	6.5	6.3	6.3	6.4
	3	6.6	6.3	6.3	6.5	6.6	6.4	6.5	6.6	6.6	6.3	6.4	6.5	6.5	6.2	6.3	6.4

APPENDIX - G

Total volatile fatty acids in the rumen fluid of experimental animals on different rations (meq/l)

ation	Days	Animal 1				Animal 2				Animal 3				Animal 4			
		Hours after feeding															
		0	2	4	6	0	2	4	6	0	2	4	6	0	2	4	6
1	1	72	103	92	82	73	102	90	81	74	103	92	80	76	101	90	82
	2	74	101	90	81	71	103	92	82	75	104	91	82	72	103	92	84
	3	75	104	91	81	75	102	93	80	73	102	94	82	75	102	90	81
2	1	77	105	93	83	75	106	94	85	76	105	93	83	77	103	94	84
	2	76	107	94	84	74	104	92	84	76	103	92	84	75	105	93	85
	3	74	103	93	85	77	104	92	84	76	103	92	83	77	104	92	83
3	1	82	111	98	89	83	110	99	88	83	108	95	90	84	109	98	89
	2	81	110	97	90	81	109	97	90	82	111	99	88	85	110	99	90
	3	82	110	98	89	84	108	98	92	82	110	97	88	82	109	98	88
4	1	85	112	102	94	84	116	104	93	83	113	104	94	82	116	104	90
	2	83	114	103	92	86	114	103	92	82	114	103	94	85	114	105	92
	3	84	115	104	91	83	114	104	93	85	115	106	92	84	115	103	90

V I T A

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