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EFFECT OF UREA TREATMENT AND CONCENTRATE PROPORTIONS ON DRY MATTER DEGRADATION OF DIFFERENT ROUGHAGES IN THE RUMEN OF JERSEY COWS

Strictly as per the compliance and regulations of :

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Abstract - A study was conducted to determine the interaction of roughage quality and urea-ammonization on the luminal degradation properties of low quality roughage diets. Four rumen fistulae Jersey cows were fed on a basal diet of either urea-treated or untreated *Eragrostis uvula* hay. These basal diets were supplemented with concentrate composed of maize meal (78%) and cotton seed cake (22%). The concentrates contributed 0, 25, 50 and 75% of the total ration and hay the rest. The experiment consisted of 6 periods. Each period lasted 19 days, comprising 12 days of adaptation to the experimental diet followed by 6 days degradability measurements and 1-day collection of rumen fluid. During each period the 4 cows were randomly allocated to 4 of the 8 dietary treatments, ensuring that each diet was fed to 3 animals during the entire experimental period.

The pH of the rumen fluid ranged between 6.5 and 6.8 for all diets. Rumen ammonia (NH_3) concentration was higher (*P<0.002*) when the basal diet consisted of urea-treated hay. Increasing the concentrate proportion in the diet had the desired effect of increasing rumen NH_3 concentration without severely affecting the pH. Urea-ammonization increased (*P<0.0001*) the slowly degradable fraction (B), potential degradability (PD), effective degradability (ED) of dry matter (DM), decreased (*P>0.05*) lag time (LT) but had no effect on the rate of degradation (c) of DM. Maximum and minimum degradability values of the B-fraction, PD and ED of DM were obtained at the 25 and 75% concentrate levels, respectively for both urea-treated and untreated diets. Within urea-ammonization, roughage type increased (*P<0.001*) the B-fraction, PD and ED of DM. Ryegrass degraded almost three to four times faster than urea-treated oat or untreated wheat straw. Urea-ammonization was less effective in increasing DM degradation rate of ryegrass compared to wheat straw. Results show that low quality roughages such as wheat straw benefited relatively the most from urea-ammonization.

Keywords : urea-ammonization, rumen ammonia, rumen pH, dry matter, fiber, roughage, degradability.

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I. Introduction

Other the last two or three decades there has been a lot of research conducted to determine the benefit of using low quality roughages in livestock feeding in the tropics, particularly during the dry season when green pasture resources area not available. These roughages contain 70-80% cell wall (CW) components, which represent potential energy for ruminant animals. Availability of this energy to the animal is generally limited by the low voluntary intake, the chemical association with lignin and CW carbohydrates, and physical limitation of the CW components to microbial fermentation. Despite the limiting features roughages have enormous potential and can be used as sole feed, if their feeding value is improved.

Considerable efforts have been made worldwide to find ways of modifying roughages to improve degradability and upgrade their nutritive value to feed ruminants. Some of the methods for improving the availability of energy in roughages for ruminants involve treatment with ammonia (Sandston and Cox worth, 1984), Noah (Dixon and Parra, 1984; Escobar *et al*., 1984) and urea (Had jipanayiotou, 1982a; Colette and Kissinger, 1984; Dias-Ad-Silva and Sandston, 1986). Urea is one of the major chemical agents used to improve the nutritive value of cereal straws and other fibrous by-products (Ray *et al*., 1989; Got *et al*., 1991; Tune *et al*., 1991; Ghana *et al*., 1993). Treatment with urea can break the ester bonds between lignin, hemicelluloses and cellulose, and physically cause structural fiber to swell. It has been suggested (Mason *et al*., 1988; Many chi *et al*., 1992) that urea-ammonization affects CW composition and improves extent of rumen degradability.

Eragrostis uvula is a popular hay grass, produced in vast quantities in Natal, with a mean crude protein (CP) content of less than 6 g kg^{-1} (Galloway, 1980), which does not meet the minimum dietary CP concentration required for milk producing dairy cows (Flacon sky *et al*., 1993). A large proportion of the potential hay crop is lost each year because difficulties are experienced with harvesting the hay at the correct

Global Journal of Science Frontier Research (D) Volume XIII Issue VIII Version I Year 2013

time. As a result a large proportion of the *E. uvula* hay produced is of little feed value. If urea has the same effect on *E. uvula* hay as on cereal straws then urea-ammonization of such low quality hay could increase its potential as a ruminant feedstuff. Concentrate supplementation for such low quality roughages also increase the rumen fermentation due to the supply of readily fermentable energy. However, it has been reported that high concentrate levels in the diet may reduce rumen fermentation and rumination time (Korsakov and Ryle, 1990). As a consequence, saliva production is low. It is not known; therefore, to what extent the changes in the rumen environment induced by feeding urea-treated roughages and concentrate supplements could affect fiber degradation.

The overall objective of this study was to determine how dietary manipulation and urea-ammonization affect degradation properties of roughage diets.

II. Materials and Methods

a) Study Area

The experiment was conducted at the University of Natal's Ukulinga Research Farm outside Pietermaritzburg, in the subtropical hinterland of KwaZulu-Natal Province, South Africa. It lies at 30°24'S, 29°24'E and approximately 700 m above sea level. The mean annual rainfall in the study site is 735 mm, falling mostly in summer, between October and April, and the maximum and minimum mean annual temperatures are 25.7 and 8.9°C, respectively (Camp, 1999). Light to moderate frost occurs occasionally in winter.

b) Animals

Four adult Jersey cows (average body weight of 425.5 ± SD 58.4), fitted with permanent rumen canola of 120 mm internal diameter were used in this study. They were kept in individual feedlot pens under a roofed shed with floor beddings. Cows were provided with clean water and a mineral block supplement at all time throughout the experiment.

c) Diet and Feeding

All rumen fistulae Jersey cows were fed on a basal diet composed of either urea-treated or untreated *Eragrostis uvula* hay. These basal diets were supplemented with a concentrate mixture composed of maize meal (78%) and cottonseed oilcake meal (22%). The concentrate was formulated to contain 15% crude protein (CP). Concentrate contributed 0, 25, 50 or 75% of the total ration and treated or untreated *E. uvula* hay the rest (22%). Thus 8 different dietary treatments were formed.

d) Experimental Design

The experiment comprised six periods. Each period lasted 19 days, comprising 12 days of adaptation to the experimental diet followed by 6-days of degradability measurements and 1-day of rumen fluid collection. During each period, the animals were randomly assigned to 4 of the 8 dietary treatments. It was however ensured that each diet was fed to 3 animals during the entire experiment (Table 1).

Before the initiation of the experiment, cows were allowed free access to diets to determine *ad labium* intake. Cows were then subsequently fed 80% of the *ad labium* intake to ensure complete consumption of feed so as to adhere to the roughage: concentrate ratio. Diets were fed twice a day, during morning (08:00) and afternoon (16:00).

e) Preparation of the urea ammoniated hay

Urea solution was prepared in a plastic container by adding 3 kg urea into 40 liters of water whilst stirring until all the urea was dissolved. The entire 40-litre solution was then sprayed onto 100 kg of hay (on a DM basis). Before the solution was made, a total of 240 bales of *E. uvula* hay were collected from Ukulinga Research Farm. One hundred and twenty of the 240 bales were ammoniated with urea and divided into 4 layer groups. The bottom layer, comprising 30 bales, was placed on the concrete floor. Using a 15-litre capacity plastic watering can fitted with a spray nozzle, the prepared urea solution was distributed evenly over the top surface of each layer of hay. The same procedures were applied until the fourth layer. The urea treated hay was covered with large plastic sheets and tightly sealed with tape at the four corners and round the edges with soils to exclude air. Immediately after sealing tightly, weights were strategically put on the top of the plastic sheet to hold it down. After 5 weeks, the treated hay was opened and aerated before feeding to the experimental animals. This treatment resulted in moisture content of approximately 35%, as calculated according to Chemist and Kaolin (1997). Representative samples of hay were taken for chemical analysis prior to and after treatment.

f) Preparation of roughages for rumen incubation study

Samples (2 kg) of 10 different roughages were chosen for this study. They were collected from different parts of South Africa. The experimental roughages were wheat (*Tritium sativa*) straw, barley (*Horde vulgar*) straw, coast cross (k_{11}) (*Condon* hybrid) hay, veldt hay (natural grass), oat (*Avenal sativa*) straw, oat (*Avenal sativa*) hay, maize (*Zeal Mays*) Stover, kikuyu (*Pennisetum clandestine*) grass, weeping love grass (*Eragrostis uvula*) hay and Italian ryegrass (*Folium multiform*).

The experimental barley, wheat and oat straws examined in this study originated from the Western Cape Province and oat hay from the Free State Province. The rest of the roughages were collected from Ukulinga Research Farm. Italian ryegrass was collected (cut) fresh and then sun-dried before use. Each sample was sub-divided into two equal portions. Each portion was then treated with or without urea. The urea solution was wholly distributed over 1 kg of roughage. Addition of the urea solution would increase the moisture content of the roughages to 35%. Treated roughages were sealed tightly and stored at room temperature for 5 weeks in plastic bags. Immediately after opining, the different roughages, including the untreated ones, were sun-dried, chopped fine by hand and ground through a2-mm screen in a laboratory mill.

g) Nylon bag incubation procedure

About 3 g of each ground forage sample was weighed into labeled nylon bags (ANKOM Co, Fairport, New York, USA; internal dimensions: 5 cm x 9 cm; pore size 50 μm). The bags were tied to a stainless steel disc with 10 evenly spaced small holes drilled through the periphery of the disc serving as anchor points. The bags were incubated (in duplicate per time interval) in the rumen for 120, 96, 72, 48, 24, 12, 6 and 3 h sequentially. The treated samples were incubated in the rumen of animals fed treated hay, while untreated samples were incubated in animals given untreated hay. Immediately after removal from the rumen, the bags, including the zero hour ones, which had not been incubated but soaked in warm water for one hour, were washed in 6 cycles (each lasting 4 minutes) in a semi-automatic washing machine. The washed bags were then dried in a forced draught oven at 60°C for 48 hours, cooled in a dedicator and weighed.

h) Rumen pH and ammonia concentration

After each incubation period, animals were maintained on the same diets and rumen fluid was collected from each animal for determination of ammonia (NH_3) concentration and rumen pH during the following times after morning feeding: 2, 4, 6, 8, 10, 12 and 24 hours. Immediately after collection, the rumen fluid was strained through a double layer of cheesecloth. Rumen pH was measured using a Crimson portable pH model 507 (Crimson Instruments, SA. 08328 Allele, and Barcelona, Spain). Samples of about 100 ml were put in 250 ml containers to which 5 drops of concentrated sulfuric were added and stored in a freezer maintained at -20°C until they were needed for NH_3 analysis.

i) Chemical analysis of basal diet and concentrate

Dry matter, organic matter (OM) and ash were analyzed using the procedures described by the Association of Official Analytical Chemists (AOAC, 1990). Nitrogen (N) or crude protein (CP) [(6.25*N)] content in feeds was determined using an automatic protein determinate (LECO FP2000, LECO, Pretoria, South Africa). Rumen NH_3-N concentration was measured using an auto-analyzer with no sample preparation. Neutral detergent fiber and acid detergent fiber (ADF) contents in feeds were analyzed according to Van Sorest *et al.* (1991) and hemicelluloses were estimated as the difference between NDF and ADF.

j) Calculations and statistical analysis

The degradation of DM was estimated by fitting the non-linear model proposed by McDonald (1981) and modified by Hanoi (1988) to the degradation data of each component: variables were determined using the secant method (SAS, 1987).

$$P = A + B\,[1 - \exp^{-c\,(T - LT)}] \qquad (1)$$

Where P is the disappearance of DM or fibre fraction at time T, A = the water soluble fraction (washing losses) and is considered immediately degradable at time zero, B = the degradable part of the insoluble fraction, c = rate of disappearance of the degradable fraction "B", T = time of exposure and LT = the lag time. The PD was calculated as (A + B). A passage rate (k) of 0.03 h^{-1} was assumed in order to calculate ED of DM (Bonsai *et al.*, 1994; Nashua *et al.*, 1998a):

$$ED = A + B \times c/(k + c) \qquad (2)$$

The model used for statistical analysis of DM degradation parameters was:

$$Y_{ijklm} = \mu + A_i + P_j + U_k + C\,(U)_{kl} + F\,(U)_{km} + \epsilon_{ijkl} \qquad (3)$$

Where

Y = individual observation;

μ = overall mean;

A = animal effect;

P = period effect;

U = effect of urea-ammonization;

C (U) = effect of concentrate within urea-ammonization;

F (U) = effect of roughage within urea-ammonization; and

ϵ = random variation (assumed independent, identical and normally distributed).

The model used for the analysis of rumen NH_3 and rumen pH was:

$$Y_{ijklm} = \mu + T_i + TA_{ij} + TP_{ik} + TC_{il} + TU_{im} + TC\,(U)_{ilm} + \epsilon_{ijklm} \qquad (4)$$

Where

Y = individual observation;

μ = overall mean;

T = effect of time;

A = animal effect;

P = period effect;

C = effect of concentrate;

U = effect of urea-ammonization;

C(U) = effect of concentrate within urea- ammonization; and

ϵ = random variation (assumed independent, identical and normally distributed).

Time was introduced in the model as a repeated measure.

III. Results

a) *Chemical composition of the feeds*

The chemical composition of the urea-treated and untreated roughages is given in Table 2. Urea-ammonization resulted in marked increase in N content. There was a wide variation in the chemical composition of the treated and untreated roughage samples. Most of the roughages (Table 2) were characterized as high fibrous feedstuffs, with a high NDF value but low CP content. NDF and hemicelluloses contents of most feeds were decreased while ADF was increased due to urea-ammonization. Among the untreated roughages, ryegrass had the highest CP content, followed by coast cross hay, oat hay, maize Stover and the lowest was barley straw in descending order. The rest of the untreated roughages fell in between the two extremes.

b) *Ammonia concentration and pH in the rumen*

The least square means of the effects of urea-ammonization of dietary roughages and varying concentrate proportions on rumen NH_3 concentration and pH are given in Table 3. Urea-ammonization (*$P<0.01$*) and concentrate proportions (*$P<0.001$*) increased NH_3 concentration in the rumens of Jersey cows but concentrate proportions within urea-ammonization had no effect (*$P>0.05$*). The lowest and highest rumen NH_3 concentrations were observed at 2 and 4 hrs, respectively, after feeding for animals fed urea treated hay, while for those on the untreated hay the lowest and the highest were recorded at 24 and 4 hrs after morning feeding. The profile of rumen NH_3 concentration of the untreated diet was maintained at a lower level than for urea-treated diet throughout the period of measurement.

As shown in Table 3, the effect of urea-ammonization and concentrate proportions on rumen pH levels was not significant (*$P>0.05$*). There was, however, a tendency for increased (*$P<0.098$*) rumen pH in animals fed urea-treated diets. Concentrate levels within urea-ammonization had no effect on rumen pH.

c) *Degradation of Dry Matter*

i. *Effect of roughage type*

The effect of roughage type within urea-ammonization on DM degradability of incubated roughages (treated and untreated) is given in Table 4. Within urea-ammonization, roughage type affected (*$P<0.0001$*) all the degradability parameters of DM.

The slowly degradable fraction of untreated roughages varied from 442 g kg^{-1} of wheat straw to 650 g kg^{-1} of veldt hay with a mean value of 527 g kg^{-1}, while for urea-treated roughages it varied from 483 g kg^{-1} of oat hay to 742 g kg^{-1} of veldt hay with a mean value of 599 g kg^{-1}. The rate of degradation of DM of untreated roughages varied from 0.022 h^{-1} for wheat straw to 0.087 h$^{-1 \text{ for}}$ ryegrass, while for urea-treated roughages it varied from 0.022 h^{-1} for oat straw to 0.082 h^{-1} for ryegrass. Ryegrass degraded almost three to four times faster than urea-treated oat straw. The potential degradability ranged from 625 g kg^{-1} of untreated wheat straw to 950 g kg^{-1} of ryegrass, and from 733 g kg^{-1} of treated wheat straw to 964 g kg^{-1} of treated ryegrass. The effective degradability was lowest in untreated wheat straw (370 g kg^{-1}) and highest in ryegrass (799 g kg^{-1}), while in treated roughages wheat straw had the lowest (434 g kg^{-1}) and ryegrass the highest (797 g kg^{-1}) effective degradability. For the untreated feeds the lag time ranged from 0.6 h in *E. uvula* hay to 3.2 h in veldt hay, and from 0.3 h in treated oat straw to 3.0 h in treated veldt hay.

ii. *Effect of urea-ammonization*

The main effect of urea and concentrate proportions within urea-ammonization nod degradability of treated and untreated roughages is given in Table 5. Urea-ammonization increased (*$P<0.0001$*) the B-fraction, PD and ED, decreased (*$P>0.05$*) the lag time that precedes the onset of degradation of DM but had no effect on rate of degradation of DM.

iii. *Effect of concentrate proportion*

Concentrate proportion affected (*$P<0.05$*) the B-fraction, PD, LT and ED but had no effect (*$P>0.05$*) on the rate of degradation of DM. For both urea-treated and untreated roughages, the B-fraction, the PD and the ED of DM increased to their maximum at 25% concentrate levels. Beyond this level, they decreased with increasing concentrate level, reaching a mini mum at 75% concentrate level (Table 5). The pattern of decrease of each of these parameters was gentle for treated but rapid for untreated ones.

d) *Relationships Among Variables*

i. *Correlation of chemical constituents with degradation of roughages*

The degradability parameters: c, PD and ED were highly correlated (*$P<0.0001$*) with the concentration of CP, ash, ADF and NDF (Table 6). The degradability of DM as measured by the above parameters increased with increasing CP and ash contents but decreased in the direction of increasing concentration of either NDF or ADF.

IV. Discussion

a) *Chemical composition*

Urea-treated diets had higher N content than untreated ones due to urea-ammonization, as was reported previously (Colette and Kissinger, 1984; Brand *et al.,* 1991). Urea-ammonization generally caused a reduction in the NDF and hemicelluloses contents of the low quality roughages. It was the reverse for the high quality roughages especially ryegrass and oat hay. Similar results regarding NDF and hemicelluloses contents of low quality roughages have been reported before (Colette and Kissinger, 1984) due to soul bilization of hemicelluloses (Van Sorest *et al.,* 1983/84; Mason *et al.,* 1988). Urea-ammonization may have removed some linkages within hemicelluloses and thus enhanced their solubility in detergent solution.

b) Rumen Environment

Rumen-NH_3 ammonia concentration steadily increased with increasing concentrate proportion in the diet. The highest DM degradation was observed when the mean value for rumen-NH_3 was close to 50 mg/l recommended by Setter and Slyer (1974). Ammonia is the preferred source of N for a large proportion of rumen microbes (Bryant and Robinson, 1963). The results of the present study indicate that the urea-treated hay, compared to the untreated diets, caused an increase in the DM degradation of the roughages. This might be attributed to the fact that urea treatment of basal diets provided more fermentable energy and N to the rumen microbes than untreated diets (Van Sorest *et al.,* 1983/84; Got *et al.,* 1991; Tune *et al.,* 1991). Although the concentrate level had no effect ($P>0,05$) on the luminal pH of cows, it tended to be lower in cows receiving 50 and 75% concentrate than in cows receiving 25% concentrate. This might have reduced the extent of DM degradability in the rumen of cows.

c) Effect of roughage type on dry matter degradability

The difference observed between the degradable parts of the insoluble fraction, the potential degradability and the effective degradability of DM of untreated and urea-treated materials might be related to the quality of the roughages before the treatment. Roughages such as barley, wheat and oat straw, coast cross hay, *E. uvula* hay and maize Stover, unlike ryegrass and oat hay, consist of cell walls that have undergone secondary thickening (Adebowale and Nakashima, 1992; Jung and Allen, 1995; Wilson and Martens, 1995) consequently they are very slowly degraded. This may explain why the washing losses of ryegrass and oat hay were almost two times higher than for the rest of the roughages. The high potential degradability values for ryegrass followed by oat hay resulted partly from very high washing losses of these roughages. This could be linked to their low NDF concentrations since the potential degradability of the roughages was found to be negatively correlated ($r = -0.797$, $P<0.0001$) to NDF. This observation confirms a report that DM digestibility was positively correlated to crude protein content and negatively correlated to crude fiber, NDF and ADF (Manson, 1982b). This may also explain why wheat, oat and barley straws had low effective DM degradability values. The low potential degradability of wheat, oat and barley straws, veldt, Kikuyu and *E. uvula* hays are closely linked to their low values of washing losses. The high effective degradability of DM for the ryegrass and oat hay before urea-ammonization could be linked to their low NDF concentrations.

Mature plants (straws) like barley, wheat and oat straw, *E. uvula* hay, coasters, hay and maize Stover are more lignified than the young grasses (ryegrass and oat hay). The deposition of lignin polymer commences with the initiation of secondary wall thickening (Trachoma *et al.,* 1993). In addition to deposition of lignin in these plants during secondary wall thickening, there is apparently an incorporation of some of the arabinoxylan ferulae esters of the primary wall into cross-linkages of the xylems to lignin (Imam *et al.,* 1990) and p-comedic acid (Lam *et al.,* 1992). The phenol nature of lignin developed during the secondary wall thickening may act as an enzyme inhibitor and interfere with the digestion of cell wall components (Van Sorest, 1994). Thus, the high slowly degradable fraction, PD and ED values of NDF (not reported) observed in this experiment, in ryegrass and oat hay may be attributed to the low levels of soluble phenol compounds as compared to wheat, barley and oat straws. These compounds are present in most mature grasses (Hartley *et al.,* 1985) and were reported to be linked to lignin, consequently limiting the degradability of cell walls (Thunder, 1985). Non-lignified tissues may also be poorly degraded due to binding with low molecular weight phenol compounds (Vadiveloo and Fidel, 1992).

d) Effect of urea-ammonization on the degradability of dry matter

Significantly higher rumen-NH_3 concentration may partly be responsible for a better rumen environment for roughage degradation in the animals fed urea-treated diets. The improvements observed in the degradability parameters of DM following urea treatment of the roughages could in part be attributed to the increased availability of carbohydrates in the dietary fiber fractions for microbes. According to Akin (1989), it is likely that any change in the degradation of the basal diet as a result of an increase in microbial activity may depend on the number of available sites for microbial attachment.

Treatment with urea increases the B-fraction. The mathematical procedure used to derive degradation parameters shows that an estimate of "B" is negatively correlated with the rate of degradation. Consequently, an increase in the B-fraction following urea-ammonization might reduce the possible effect of treatment on the rate of degradation.

The effect of urea-ammonization might have been more pronounced on the degradability of low quality roughages, such as wheat straw, relative to good quality roughage like ryegrass because urea-ammonization works best on low quality roughages. It has been observed (Got *et al.,* 1991) that the extent of improvement in degradability following ammonia treatment of Golden Promise (a variety of wheat straw which had a DM degradability of 41.0% before treatment and 53.5% after treatment) was about four times higher than the corresponding value in Doublet (a variety of wheat straw which had a DM degradability value of 57% before ammonia treatment and 59% after treatment), indicating that the effect of ammonization was more pronounced for materials of lower inherent degradability. Utah et *al.* (1986) reported that the poorest quality straw benefited the most from urea-ammonization.

e) Effect of concentrate proportions on the degradation of dry matter

Although the highest rumen-NH_3 concentration was recorded in animals fed urea-treated *E. uvula* hay supplemented with 75% concentrate, its failure to improve the dry matter degradability of the incubated roughages may relate the fact that higher concentrate proportions in a diet may lower the cellulolytic activity of rumen microbes. Gal yean and Goatish (1993) proposed that the inclusion rates of concentrate in a diet for dairy and beef cattle should be less than 40 a d 20% of the total ration, respectively. In the experiment reported here, however, addition of concentrate up to 25% to urea-treated and untreated hay resulted in positive associative effects on dry matter degradation. Similar results were reported in another study (Niangua *et al.,* 1993) after goats and sheep were offered urea-treated sorghum stover with less than 25% concentrate supplementation. Beyond the 25% concentrate level, there was a negative associative effect on dry matter degradation. The pattern of negative effect was less pronounced in the urea-ammoniated diets. This might be due to the fact that urea is alkaline, which can neutralize the acidity caused by adding higher amount of concentrate in the diets of cows. Flacon sky *et al.,* (1993) also reported that dry matter degradability of ammonia-treated and untreated straw decreased when dietary straw was replaced by concentrate and that the extent of depression was higher for the untreated straw.

V. Conclusion

The results of this study have shown that urea-ammonization increased CP content as well as decreased NDF and hemicellulose contents of roughages. Addition of 25% concentrate in either urea-ammoniated or untreated *E. uvula* hay diets increased DM degradation. Increasing concentrate level beyond 25% of the diet was associated with decreased *in Sacco* DM degradation. It was observed that urea-ammonization tended to reduce the negative effect of feeding high concentrate compared to untreated diets. Therefore, this study suggests that there is much to gain by treating low quality roughages.

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Table 1 : Experimental design of feeding program (regime) in different periods

Periods	Treated : Concentrate ratio (T : C)**				Untreated : Concentrate ratio (UT : C)**			
	100 : 0	75 : 25	50 : 50	25 : 75	100 : 0	75 : 25	50 : 50	25 : 75
P_1	1***			4	3	2		
P_2		1	4				3	2
P_3	2	3	1				4	
P_4			2	1		4		3
P_5	3	2			1			4
P_6				3	4	1	2	

*P_1, P_2, P_3,...P_6 = Period.
**T : C = Urea-ammoniated hay : Concentrate ratio; UT : C = Untreated : Concentrate ratio.
****1 – 4 = Animal number.

Table 2 : Chemical composition (g kg^{-1} DM) of feed ingredients and incubated sample of feeds

Items	Urea	DM	CP	Ash	NDF	ADF	HEM
Feed ingredients							
E. curvula hay	1	937	88.3	56.1	754	431	234
E. curvula hay	0	938	64.2	59.2	752	420	332
Maize meal		897	80.4	11.1	85	24	61
Cotton seed cake		895	363.5	56.7	287	234	544
Incubated roughages							
Barley straw	1	938	79.4	52.7	739	523	217
E. curvula hay	1	923	10.1	59.2	772	432	340
Coastcross hay	1	924	153.2	69.8	758	419	339
Kikuyu hay	1	909	117.6	78.9	659	381	279
Maize stover	1	912	124.3	46.9	720	434	287
Oat hay	1	887	177.5	105.4	479	318	162
Oat straw	1	938	80.4	68.5	724	516	208
Ryegrass	1	913	348.6	139.4	495	247	248
Veld hay	1	924	106.0	60.6	721	492	230
Wheat straw	1	932	76.0	48.3	727	518	209
Barley straw	0	930	37.0	54.5	795	541	254
E. curvula hay	0	936	71.2	58.1	765	426	339
Coastcross hay	0	951	118.3	70.2	764	398	369
Kikuyu hay	0	930	75.7	77.2	692	365	327
Maize stover	0	929	85.9	46.3	720	448	272

Oat hay	0	905	97.0	107.9	487	302	185
Oat straw	0	937	43.4	69.2	769	531	239
Ryegrass	0	924	302.7	136.2	438	233	206
Veld hay	0	945	64.7	79.3	698	454	245
Wheat straw	0	935	45.4	56.9	752	521	230

1, Urea-ammoniated; 0, Untreated; HEM, hemicelluloses (HEM = NDF – ADF).

Table 3 : Least square means of the main effects of urea-ammonization of dietary roughages and variation in dietary concentrate proportion on the rumen ammonia concentration and rumen pH in Jersey cows

Parameters	Urea		SED	P value	Concentrate (%)				SED	P value
	0	1			0	25	50	75		
NH_3 mgl^{-1}	49.9	66.9	2.54	0.002	38.2	46.8	71.5	77.0	3.59	0.000
pH	6.6	6.5	0.03	0.098	6.7	6.6	6.5	6.5	0.05	0.169

0, untreated; 1, urea-ammoniated.

Table 4 : Effect of roughage type within urea - ammonization on dry matter degradability of treated and untreated roughages incubated in the rumens of cows fed either treated or untreated hay with or without concentrate

Feed type	Urea	Degradation parameters				
		B ($g\ kg^{-1}$)	c (h^{-1})	PD ($g\ kg^{-1}$)	ED ($g\ kg^{-1}$)	LT (h)
Barley straw	1	603	0.026	812	479	2.2
E. curvula hay	1	728	0.031	853	467	1.9
Kikuyu grass	1	551	0.043	755	517	0.9
Coastcross hay	1	622	0.032	808	498	2.7
Maize stover	1	593	0.032	799	504	1.5
Oat hay	1	483	0.050	912	723	0.6
Oat straw	1	578	0.022	788	439	0.3
Ryegrass	1	572	0.082	964	797	1.8
Veld hay	1	742	0.027	882	476	3.0
Wheat straw	1	517	0.023	733	434	1.6
Barley straw	0	559	0.027	719	423	2.2
E. curvula hay	0	629	0.025	787	442	0.6
Kikuyu grass	0	447	0.032	665	448	3.2
Coastcross hay	0	578	0.029	730	435	1.5
Maize stover	0	485	0.026	711	448	0.7
Oat hay	0	455	0.066	881	731	1.4
Oat straw	0	464	0.029	635	397	2.1
Ryegrass	0	565	0.087	950	799	1.5
Veld hay	0	650	0.026	808	453	3.2
Wheat straw	0	442	0.022	625	370	1.9
SED		46.3	0.011	46.3	26.9	1.2
Effect feed type (urea)		0.0001	0.0001	0.0001	0.0001	0.0001

1, Urea-ammoniated; 0, Untreated; c, rate of degradation of slowly degradable fraction; B, slowly degradable fraction; h, hour; PD, potential degradability; ED, effective degradability; LT, lag time.

Table 5 : Effect of urea-ammonization and concentrate proportions on dry matter degradability of treated and untreated roughages incubated in the rumen of Jersey cows

Concen trate (%)	Urea	Degradation parameters				
		B (g kg^{-1})	c (h^{-1})	PD (g kg^{-1})	ED (g kg^{-1})	LT (h)
0	1	596	0.036	827	534	1.4
25	1	614	0.040	846	548	1.6
50	1	592	0.038	823	541	2.3
75	1	594	0.033	826	511	1.3
0	0	529	0.039	753	507	2.3
25	0	553	0.039	776	511	1.8
50	0	525	0.036	749	488	1.9
75	0	503	0.034	727	473	1.4
Main effect of Urea						
	1	599	0.037	831	533	1.6
	0	527	0.037	751	495	1.8
SED (conc level)		32.8	0.0075	32.8	19.0	0.81
SED (urea)		16.4	0.0038	16.4	9.5	0.41
Effect of conc (urea)		0.0353	0.2589	0.0353	0.0001	0.0256
Urea		0.0001	0.9706	0.0001	0.0001	0.2804

1, Urea-ammoniated; 0, Untreated; c, rate of degradation of slowly degradable fraction; B, slowly degradable fraction; h, hour; PD, potential degradability; ED, effective degradability; LT, lag time

Table 6 : Correlation between the chemical composition of roughages and the degradability parameters of dry matter

Chemical constituents	c(h^{-1})		PD (g kg^{-1})		ED (g kg^{-1})	
	1	0	1	0	1	0
Crude protein	0.88**	0.83**	0.67**	0.72**	0.81**	0.80**
Ash	0.85**	0.93**	0.75**	0.78**	0.89**	0.91**
NDF	-0.86**	-0.94**	-0.74**	-0.80**	-0.95**	-0.97**
ADF	-0.86**	-0.84**	-0.67**	-0.77**	-0.88**	-0.87**

1, urea treated; 0, untreated; NDF, neutral detergent fiber; ADF, acid detergent fiber; c, rate of degradation of slowly degradable fraction; h, hour; PD, potential degradability; ED, effective degradability.