Effects of Urea Levels and Treatment Durations on Chemical Composition and *In Vitro* Dry Matter Digestibility of Maize Stover

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ABSTRACT

Effects of urea level and treatment duration on the chemical composition and in vitro dry matter digestibility (IVDMD) of maize stover was studied by treating the stover of improved maize variety with 4, 5 or 6% urea levels for 1, 2 or 3 weeks under laboratory condition of 25°C. There were significant differences in crude protein (CP), neutral detergent fiber (NDF) and IVDMD both among the urea levels and the treatment durations. The highest CP content of 16.9% was observed for the stover treated with 6% urea followed by 15.9% for the stover treated with 5% urea. With regard to treatment durations, there was no difference ($p>0.05$) in CP content between the 2 and 3 weeks treatment durations. Interaction between the two factors was significant ($p<0.05$) only for NDF and IVDMD. Treating the stover with 5% urea for a period of 2 weeks resulted in 76.6% NDF and 61.2% IVDMD both of which were not significantly different ($p>0.05$) from treating the stover with 6% urea for either 1, 2 or 3 weeks. Therefore the former combination of urea level and treatment duration was recommended to be optimum to treat maize stover.

Key words: chemical composition, digestibility, maize stover, treatment duration, urea levels

INTRODUCTION

Crop residues are the major source of animal feeds in mixed crop livestock farming systems especially during the dry period when green forages are scarce. Nutritionally, these feed resources are generally low in essentials nutrients, especially crude protein, and are high in fiber content. This calls for investigation to improve or upgrade their nutritive values. Towards this end, much efforts have been directed to up-grading them through physical and chemical treatments as well as strategic supplementation to alleviate their deficiencies.

Of the chemical treatments, using the nitrogenous alkali has been found to be advantageous as compared with using sodium hydroxide mainly because the increase in the microbial requirement for nitrogen when the potential digestibility increases being supplied by ammonia absorbed by the straw. According to Zhang and Yan (2002), ammoniation usually increased digestibility by 20% and crude protein content up to 1 to 2 times. It can as well improve palatability and consumption rate. Among the various ways of ammoniation, the one with urea is preferred because urea is less hazardous to use, cheap and easily obtainable compared with sodium hydroxide or aqueous and anhydrous ammonia. Its use also improves the nitrogen content of the

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straws.

Regarding urea application rate, the level of 4 to 5 kg urea for treatment of 100 kg dry straw has been widely used in many countries such as Thailand, China, Sri Lanka, etc. In other countries, levels as high as 6 to 7 kg per 100 kg dry straws were used. Based on the available knowledge for urea treatment, Said and Wanyoike (1987) recommended that smallholders in Kenya should treat their maize stover with 5% urea for two weeks.

Regarding the effects of urea treatment on chemical composition of the treated straw Wongsrikeao and Wanapat (1985) reported 60.8% dry matter (DM) and 6.8% CP for rice straw treated with 6% urea- as compared to 92.8% DM and 3.8% CP for the untreated straw. Similarly, the dry matter digestibility of the treated straw was higher (55.4%) than that of the untreated straw (43.2%). Wanapat *et al. (*1986) also observed an enhanced CP content (21 versus, 139 g per kg DM) and both reduced NDF and acid detergent fiber (ADF) contents of barley straw due to 5% urea treatment. With regard to effects of treatment durations, Tran and Nguyen (2000) observed an increasing trend in both CP and crude fiber (CF) contents with increasing treatment durations.

Though it is generally known that urea treatment has a considerable advantage in terms of improving the nutritional value of straws, the effects are known to vary with environmental conditions, residue type and variety. So far there has been no research conducted in Ethiopia regarding urea treatment of maize stover, one of the important and abundantly produced crop residues in arid and semi-arid areas. Therefore, this work was designed to investigate the optimum urea level and treatment duration that would bring about an improved nutritive value of maize stover under Ethiopian conditions.

MATERIALS AND METHODS

This experiment was conducted at Adami Tulu Agricultural Research Center which is 167 km south of Addis Ababa. The center is located at an elevation of 1650 m above sea level (ATARC, 1998). The area receives a mean annual rainfall of 800 mm, most of which fall during the months of June to September. Mean maximum and minimum temperatures ranges from 25 to 28°c and 8 to 12°c, respectively.

Treatment of the stover

Sun dried maize stover of improved maize variety was chopped into 3 to 5 cm and the chopped stover was treated at a room temperature of 24°c using a 3×3 factorial experiment involving three levels of urea (4, 5 and 6% of the dry stover weight) and three treatment durations (7, 14 and 21 days). Each combination of urea level and treatment duration was carried out in duplicates. In all cases, 80 g of the urea solution containing 10 g cane molasses and the amount of urea giving the respective percentage was added per 100 g of the dry stover. This was thoroughly mixed in a bucket and was transferred into a plastic bag squeezed to remove excess air (to make it air tight). Then it was sealed and ensiled for the pre-determined durations mentioned. After treatment, the stover was aerated for 2 to 4 hours and representative samples were taken and kept frozen for total nitrogen determination. The remaining straws were dried to constant weight at 65°c and were ground prior to other chemical analyses.

Chemical analyses

Dry matter, ash and Kjeldhal nitrogen were determined according to the procedures of AOAC (1990). The frozen samples were thawed, then chopped into small pieces and well blended before they were analysed for nitrogen content. NDF was analysed using the procedures described by Goering and Van Soest (1970). *In vitro* dry matter digestibility (IVDMD) was determined by the two stage methods of Tilley and Terry (1963). CP percentage was calculated as % N $\times$ 6.25.

Statistical analyses

Fixed effects of the levels of urea concentration, treatment duration and their interaction on chemical composition and digestibility of the treated stover were analysed as a 3 $\times$ 3 factorial experiment in completely randomized design using the general linear model procedure of SAS (SAS, 2000). Duncan Multiple Range Test was used to test the difference among treatment means. The statistical model used was:

$$Y_{ijk} = \mu + U_i + D_j + UD_{(ij)} + \varepsilon_{ijk}$$

Where, Y_{ijk} = Response variable (Chemical entities and IVDMD)

μ = Overall mean

U_i = Effect of i^{th} urea level (i = 1, 2, 3)

D_j = Effect of j^{th} treatment duration (j = 1, 2, 3)

$UD_{(ij)}$ = Effect of i^{th} urea level at j^{th} treatment duration

ε_{ijk} = Random error

RESULTS AND DISCUSSIONS

Effects of urea levels

The effects of urea concentration on chemical composition and IVDMD of the urea treated maize stover are given in Table 1. Urea levels affected ($p<0.05$) CP and NDF contents and IVDMD of the treated stover. CP contents, as determined from wet samples, were 14.9, 15.92 and 16.87% for the 4, 5 and 6% urea levels, respectively. In comparison with the untreated maize stover used in this study, the 4% urea treatment brought a 3.7 times increase in CP content of the stover (4.02% vs. 14.9%). This would mean a provision of sufficient nitrogen of 46 g per kg dry organic matter (DOM) (because it had 26 g nitrogen per kg organic matter (OM) and its organic matter digestibility (OMD) was 56.4) for rumen microbes. In the current study, CP content of the 5% urea treated maize stover was 1.02 percentage units higher than that of the stover treated with 4% urea, but only 0.95 percentage units lower than the one treated with 6% urea. The 6% urea level resulted in an increase of 0.15% nitrogen over the 5% urea level at 1% urea. Taking 91.58% as the DM content of the untreated maize stover and assuming the nitrogen content of urea is 46%, this increment in nitrogen content amounted to 30% of the additional urea nitrogen. This indicated the existence of high loss of nitrogen as a result of high levels of urea application. In a study conducted by Nguyen *et al.* (1998) only 17.4% of the additional urea nitrogen was fixed when rice straw was treated with 5% urea compared with 3% urea plus 0.5% $Ca(OH)_2$. These authors attributed the low increment of nitrogen to the fact that the nitrogen detected was only a

Table 1 Effects of urea concentration on chemical composition and IVDMD of urea-treated maize stover.

Parameters	Urea concentration (%)			SE
	4	5	6	
DM, %	63.46	64.07	68.91	1.84
Chemical composition, % of DM				
CP	14.90[c]	15.92[b]	16.87[a]	0.27
NDF	79.31[a]	77.25[b]	76.14[c]	0.12
Ash	8.37	7.90	8.37	0.22
IVDMD, %	55.94[c]	60.27[b]	61.26[a]	0.24

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

fraction of nitrogen chemically fixed to the cells of the straw and insoluble in water, thus being unrepresentative of the total nitrogen in the treated straw.

Chemical analysis of the untreated maize stover used in this study showed that its CP and DM contents were 4.02 and 91.58%, respectively. Based on these values, the urea nitrogen retained as percents of the added urea nitrogen for the 4, 5 and 6% urea levels were 87, 76 and 68%, respectively. These values indicated that animals could obtain a good amount of nitrogen from urea treated materials if they were fed the wet stover only after aeration for some hours. The urea nitrogen retained in the current study was higher than what Saadullah *et al.* (1981) observed for 3 and 5% urea treatments. The decreasing trend in nitrogen retained with the increasing urea levels was in agreement with the works of Chenost and Kayouli (1997) which stated that the nitrogen fixation ratio usually fell with the increase in the urea level because large amounts of free ammonia (not fixed yet) built up within the straw matter might stop or hinder hydrolysis of the urea. Compared with the 4% urea level, the 5 and 6% urea levels reduced the NDF fraction of the treated stover by about 2 and 3 percentage units, respectively. Though the differences were not significant ($p>0.05$), the increasing trend in DM content with increasing urea levels was in agreement with the findings of Saadullah *et al.* (1981). Similarly, no difference was observed in ash content among the urea levels. This was also supported by Zaman and Owen (1995) who observed no difference in ash content of barley straw treated with 3% and 6% urea.

IVDMD of the treated stover increased significantly ($p<0.05$) with the increase in urea levels. The maize stover treated with 5 and 6% urea levels had 7.7 and 9.5% higher IVDMD than the stover treated with 4% urea level. This could partly be attributed to the lower NDF contents of the stover treated with higher urea levels than the one treated with lower urea level. Saadullah *et al.* (1981) also found poorer results in digestibility for lower urea level of 3% as compared with the 5% urea level.

Effects of treatment durations

As indicated in Table 2, treatment durations had significant ($p<0.05$) effects on all the chemical entities. In all parameters, intermediate values were observed for the treatment duration of 14 days. DM content of the treated stover decreased from 68.11% in the case of treatment duration of 7 days to 66.94 and 61 39% in those of 14 and 21 days, respectively. This could be due to the difference in moisture loss that might occurred during aeration. In studying the effects of urea levels and preservation time on chemical composition of the treated maize stover, Tran and Nguyen (2000) also found a decreasing

Table 2 Effects of treatment durations on chemical composition and IVDMD of urea-treated maize stover.

Parameters	Treatment duration (days)			SE
	7	14	21	
DM, %	68.11[a]	66.94[ab]	61.39[b]	1.84
Chemical composition, % of DM				
CP	14.90[b]	16.05[a]	16.73[a]	0.27
NDF	78.29[a]	77.32[b]	77.09[b]	0.12
Ash	7.68[b]	7.76[b]	8.66[a]	0.22
IVDMD, %	57.88[b]	59.48[a]	60.11[a]	0.24

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

trend in DM content with increasing time of preservation. On the other hand, the ash content of the treated stover increased with the increase in treatment durations and this was also in agreement with the works of Tran and Nguyen (2000). However, the difference between treatment duration of 7 and 14 days was not significant ($p>0.05$).

Crude protein contents of the sample treated for 7, 14 and 21 days were 14.90, 16.05 and 16.73%, respectively. CP contents of the sample treated for 7 days was significantly ($p<0.05$) lower than those treated for either 14 or 21 days. The increasing trend in CP content with increasing treatment durations agrees with the works of Nguyen *et al.* (1998) which reported increased fixed nitrogen content over treatment times of 10, 20 and 30 days. According to these authors, at the beginning of urea treatment the added nitrogen existed mainly in the form of urea with free ammonia being released later from which more and more nitrogen would be fixed together with the straw. As only this fixed nitrogen could be detected while analyzing the pre-dried samples, resulting in evaporation of the free and loosely bound ammonia, the short treatment duration was likely to give lower nitrogen content than the longer treatment duration. Hence it was likely that with short treatment times the response to urea ammoniation might be reduced.

Compared with the treatment duration of 7 days, treatment duration of either 14 or 21 days significantly ($p<0.05$) reduced the NDF content of the treated stover. This was at variance with Nguyen *et al.* (1998) who observed no appreciable differences in NDF content among the rice straws treated for 10, 20 and 30 days. Treatment duration also influenced IVDMD of the stovers with stovers treated for 14 and 21 days being more ($p<0.05$) digestible than those treated only for a week. This could be due to the sufficient time allowed for the urea to act on the cell wall structure. In *in vitro* Dias-Da-Silva, *et al.* (1988) also reported a significant increase OM digestibility of the urea treated maize stover with increasing treatment time.

Combined effects of urea levels and treatment durations

Significant ($p<0.05$) interaction between the two factors (urea level and treatment duration) were observed only for NDF content and IVDMD. Combined effects of the two factors on NDF content of the treated stover are given in Table 3. There was a decreasing trend in NDF content with increasing urea level and treatment duration. The results were in favour of the 5% urea treatment for a period of 14 days as none at the higher levels of both the urea concentration and the treatment duration brought about an NDF percentage which differed significantly from that of the 5% urea treatment for a period of two weeks. This was supported by Dias-Da-Silva, *et al.* (1988) who reported ensiling with urea as being effective in reducing the NDF content, with the effects being highly dependent on time. There was a decrease in NDF content with an increase in treatment time. Tran and Nguyen (2000) also reported a decreasing

Table 3 Effects of urea levels and treatment durations on NDF content (%) of the urea treated maize stover.

Treatment durations (days)	Urea levels (%)		
	4	5	6
7	80.19^{a}	78.42^{c}	76.25^{de}
14	79.23^{b}	76.56^{de}	76.17^{de}
21	78.51^{c}	76.77^{d}	76.00^{e}

^{abcde} Means with different superscripts are different ($p<0.05$).

Table 4 Effects of urea levels and treatment durations on IVDMD (%) of the urea treated maize stover.

Treatment durations (days)	Urea levels (%)		
	4	5	6
7	55.02[f]	59.07[d]	59.55[cd]
14	55.37[f]	61.23[ab]	61.85[ab]
21	57.44[e]	60.52[bc]	62.38[a]

[abcdef] Means with different superscripts are different ($p<0.05$).

trend in crude fiber with increasing treatment duration. Such observation could be attributed to the sufficient time urea which acted upon the insoluble fractions of the cell wall components of the stover changing them into soluble fractions essential for microbial fermentation in the rumen.

The effects of urea level and treatment duration on IVDMD are presented in Table 4. Treating the stover with 5 and 6% urea levels for either 2 or 3 weeks significantly ($p<0.05$) increased IVDMD over treating it with 4% urea level for either of the duration. However, the differences among the 5% urea treatment for 2 weeks and the 6% urea treatment for either 2 or 3 weeks were not statistically significant ($p>0.05$). This was in agreement with Chenost and Kayouli (1997) who reported that higher urea application rates did not bring about a significant increase in nutritive value of the straw, despite increasing treatment costs to farmers thus limiting uptake of the technology. Under Sri Lanka condition, these authors recommended an application rate of 4% urea.

CONCLUSSIONS

Results of this study revealed that there was no statistical difference between the 5% urea treatment for 2 weeks and the 6% urea treatment for either 2 or 3 weeks in NDF content and IVDMD. This, with the added advantage in cost saving, made the 5% urea treatment for a period of 2 weeks to be more attractive than the 6% urea treatment. Moreover, though the nitrogen content of the 6% urea treatment was higher than that of the 5% urea treatment, the latter case was likely to be preferred as the nitrogen in the former case would by far be more than the requirement for rumen microorganisms and would be wasted. Except for its disadvantage in having relatively high NDF content and low IVDMD, even the 4% urea treatment was likely to be more economical than the 5% urea treatment and could be employed especially in areas where urea was highly expensive and in cases where moderate reduction in NDF and moderate increase in IVDMD were considered to be acceptable.

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