Synergistic Effect of Urea and Lime Treatment of Wheat Straw on Chemical Composition, *In Sacco* and *In Vitro* Digestibility

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ABSTRACT : Chopped wheat straw (0.5-1.5 cm) was subjected to different treatment combinations in a 5×4 factorial arrangement involving the five levels of urea (0, 2, 3, 4 and 5%, w/w) and four levels of lime (0, 2, 4 and 6%, w/w) at 50% moisture and kept for 3 wk reaction period at about 35℃ in laboratory. Treated wheat straw samples were analyzed to study the associative effect of urea and lime on chemical composition, *in sacco* and *in vitro* digestibilities. Results showed that cell wall constituents (CWC) solubilized significantly ($p<0.01$) due to urea and lime treatment on one hand and substantially increase the crude protein (CP) on the other in wheat straw. The main effect on synergism of both chemicals was noticed on organic matter (OM), neutral detergent fibre (NDF), hemicellulose (HC), acid detergent lignin (ADL) and silica by solubilising their contents as a result of considerable increase in cell contents in treated wheat straw. The respective decreases were 5.45, 13.0, 37.23, 44.95 and 26.16% in different treatment combinations. The most interesting feature of the treatment was evident by increase in ash content on each level of lime application. CP content increase upto 12.78% due to urea treatment in comparison with untreated wheat straw (2.56%). The effect of solubilization of structural carbohydrates and increased crude protein due to synergistic effect of urea and lime were clearly seen on improved digestibility of OM and DM. The increase in ISOMD, ISDMD, IVOMD, and IVDMD were 21.67, 21.67, 16.24 and 17.5 units. The increase in digestibility were relative to additions of both chemicals and digestibility values increased with increasing levels of urea plus lime concentration in different treatment combination. The maximum improvement was noticed at 4% urea and 4% lime levels at 50% moisture for 3 wk reaction period in treated wheat straw. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 7 : 1049-1053*)

Key Words : Urea-Lime Treatment, Wheat Straw, Cell Wall Constituent, Digestibility

INTRODUCTION

Wheat straw is available in huge quantities in India. However such cereal straw are poorly utilised due to presence of ligno-cellulosic complex. Several workers attempted to improve the nutritive value of such straws through chemical treatment. Sodium hydroxide and ammonia treatment of crop residues have been extensively researched (Sundstol and Owen, 1984). Both chemicals are not suitable for developing countries due to expensive and hazardous nature. However, ammoniation of straw through urea was found to be feasible in developing countries (Wanapat, 1985; Rai and Gupta, 1990). Calcium hydroxide also offers a possible replacement of sodium hydroxide and ammonia. It is a cheaper chemical and is safer than sodium hydroxide and ammonia. Calcium hydroxide have weaker base than NaOH and having potential to increase the nutritive value of straw (Saadullah et al., 1981; Sharma, 1987; Sirohi and Rai, 1998). However, uniform adoption of urea treatment technology under field conditions across the country is not possible. Under such conditions one has to look into the possibility of exploring a cheaper source of chemical with adequate efficacy. Lime is comparatively cheaper but the one problem associated with lime treated straw identified by some workers was growing of mould. However ammonia produced during ammoniation inhibits mould. Therefore, the experiment was planned to see the effect urea plus lime treatment of wheat straw on chemical composition, *in sacco* and *in vitro* digestibilities.

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Received September 11, 1998; Accepted January 27, 1999

MATERIALS AND METHODS

Treatment methodology

Wheat straw (0.5-1.0 cm) was treated with urea (0, 2, 3, 4 and 5%, w/w) and commercial lime powder (unslacked) (0, 2, 4 and 6%, w/w) in 200 g lots in triplicate using 5×4 factorial arrangement. The moisture was maintained at 50%. Both urea and lime powder dissolved in required amount of water were sprayed and mixed manually with straw. The treated material was sealed in double polythene bags and kept at about 35℃ in laboratory for 3 weeks reaction period. The available lime concentrations for reaction were 0.66, 1.32 and 1.98% at 2, 4 and 6%, respectively, as lime powder (unslacked) had only 33% solubility.

Chemical analysis of straw

Samples of treated straw were ground in a laboratory mill through a 1 mm screen. These were analysed in triplicate for DM, total ash, CP and silica according to the standard procedure of AOAC (1984).

ADF, NDF and ADL were analysed as described by Goering and Van Soest (1970). Cellulose and HC were calculated from the data of ADF and NDF as suggested by Van Soest (1982).

In sacco digestibility

In sacco DM digestibility (ISDMD) as well as *in sacco* OM digestibility (ISOMD) were determined by suspending the nylon bag (7.5×12.5 cm) in the rumen of three buffalo calves fitted with cannulae for 48 hours. The calves maintained on a standard diet consisting of normal farm concentrate mixture consisted of 40% maize, 20% wheat bran, 37% groundnut cake, 2% mineral mixture and 1% common salt. For nylon bag studies treated samples were opened at the end of the period, dried (60℃) in oven and ground in a hammer mill.

In vitro digestibility

In vitro digestibility of DM and OM was determined according to Van Soest et al. (1966). A composite sample of rumen liquor was withdrawn from same calves used in nylon bag studies. The rumen liquor taken in a thermos flask duly flushed with CO_2 and filtered through 4 layers of muslin cloth. The strained rumen liquor (SRL) was used as rumen inoculum for the determination of IVDMD and IVOMD of treated material.

Statistical analysis

The data were subjected to statistical analysis using 5×4 factorial arrangement (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Chemical composition of wheat straw significantly affected in terms of solubilization of CWC and its constituents on one hand and substantially increases the CP content on the other due to associative effect of urea plus lime treatment (table 1). Crude protein content increased significantly to 10.27 unit in comparison with untreated straw and values were increasing with increased level of urea, however lime did not show any effect on CP content. The NDF and ADL contents decreased due to associative effect of urea and lime and values were reduced to the extent 10.54 and 4.99 units in different treatment combinations in comparison with untreated wheat straw. Silica content also solubilized due to treatment and the maximum decrease was noticed 26.16% in different treatment combinations. The effects of urea and lime levels on OM, ADF, cellulose, total ash and silica were significant (table 3) and values were depicted in figure 1. Comparison of urea and lime treatment clearly indicated that lime was more effective than urea alone in solubilizing the CWC (table 1 and figure 1). The maximum effect of urea plus lime treatment was noticed at higher levels of urea (5%) and lime (6%). The interaction effect between urea and lime was significant on NDF, HC, cellulose, ADL and silica. Further it was observed that the occurrence of mould was not found in any of the treated samples due to urea plus lime treatment at 50% moisture and 3 wk period of treatment.

Results indicated that IVOMD and IVDMD were increased due to the addition of urea and lime in different treatment combinations (table 2). Similar trends were noticed in case of ISOMD and ISDMD were increased from 38.60 and 45.15% to 60.27 and 61.40%, respectively, in different treatment combinations. Both the chemicals were effective to increase the *in sacco* and *in vitro* digestibilities as respective average values of ISOMD at 0, 2, 3, 4, 5% urea and 0, 2, 4 and 6% lime levels were 50.48, 50.41, 50.15, 54.46, 55.00 and 45.08, 53.31, 54.26 and 55.75%,

Table 1. Associative effect of urea and lime treatment on chemical composition of wheat straw

Lime	Urea (%)						Urea (%)					
(%)	0	2	3	4	5	Mean	0	2	3	4	5	Mean
	CP (%)						NDF (%)					
0	2.56	7.00	8.00	10.50	13.00	8.21	80.67	79.00	78.50	78.00	78.60	78.95[a]
2	3.29	6.90	7.30	10.17	12.77	8.10	78.33	75.83	74.77	72.07	70.40	74.28[b]
4	2.80	6.97	7.77	10.23	12.50	8.05	76.23	75.27	73.77	71.97	70.33	73.51[c]
6	2.83	6.80	7.80	10.75	12.83	8.20	76.33	74.27	73.60	70.57	70.13	72.98[d]
Mean	2.87[a]	6.92[b]	7.72[c]	10.41[d]	12.78[e]	-	77.89[a]	76.09[b]	75.16[c]	73.16[d]	73.10[cd]	-
	HC (%)						ADL (%)					
0	30.00	28.00	26.80	27.70	27.40	27.98[a]	7.20	8.90	8.66	8.20	8.00	8.97[a]
2	26.87	23.60	20.13	23.20	19.40	22.64[b]	9.50	8.77	8.53	7.67	7.00	8.29[b]
4	26.30	23.77	21.13	21.90	18.83	22.39[b]	7.20	8.60	8.03	6.99	6.43	7.45[c]
6	25.58	22.73	20.33	23.17	19.27	22.22[b]	6.97	8.33	7.83	6.63	6.11	7.17[d]
Mean	27.18[a]	24.53[b]	22.22[c]	23.99[b]	21.22[d]	-	8.69[a]	8.65[a]	8.25[b]	7.37[c]	6.89[d]	-

Different superscripts in a row and column are significant at $p<0.01$.

CP-Crude protein, NDF-Neutral detergent fibre, HC-Hemicellulose, ADL-Acid detergent lignin.

respectively. The average values for IVOMD were 53.19, 50.03, 53.78, 55.51 and 57.41% and 49.63, 51.73, 56.10 and 58.50% at 0, 2, 3, 4, 5% urea 0, 2, 4 and 6% lime levels, respectively. The digestibility were increased significantly ($p<0.01$) with addition of urea lime levels and higher concentration of both the chemicals showed maximum increase in ISOMD and IVOMD values (table 2). Similar effects were noticed in case of ISDMD and IVDMD. The maximum improvement was observed at 4% urea and 4% lime levels because 4 and 5% urea levels and 4 and 6% lime levels were comparable and the differences were not significant. The interactions between urea levels and lime levels were significant on digestibilities of DM and OM in treated wheat straw.

Further correlation was estimated between IVOMD and chemical composition presented in table 4. Correlation coefficient showed that NDF, HC and ADL were negatively correlated with IVOMD, however CP content have positive relation with IVOMD. The ADL content was shown maximum negative relation with IVOMD and r value for all the chemical constituents, i.e. NDF, HC and ADL were significant.

Table 4. Correlation coefficient (r) from linear regression equation relating to chemical composition and invitro organic matter digestibility of urea plus lime treated wheat straw

Chemical components of straw	Relation with IVOMD	Significance
CP	0.32	NS
NDF	-0.62	**
HC	-0.55	**
ADL	-0.84	**

Number of observations = 20; ** Significant at $p<0.01$.

Solubilization of CWC and increased CP content due to combined effect of urea and lime showed their impact on improving the digestibilities of DM and OM under *in sacco* and *in vitro* conditions. The increase in IVOMD (35.96%) and ISOMD (56.14%) was relative to the addition of both chemicals during

Table 2. Associative effect of urea plus lime treatment on digestibility

Lime	Urea (%)						Urea (%)					
(%)	0	2	3	4	5	Mean	0	2	3	4	5	Mean
	ISOMD (%)						IVOMD (%)					
0	38.60	40.20	45.20	48.90	52.50	45.08^{a}	45.16	45.40	49.20	52.40	56.00	49.63^{a}
2	48.33	50.67	52.00	60.27	55.27	53.31^{b}	46.20	53.25	52.80	52.50	53.90	51.73^{a}
4	56.10	54.83	51.87	55.17	53.33	54.26^{b}	60.00	46.00	55.70	58.80	60.00	56.10^{b}
6	58.90	55.93	51.50	53.70	58.93	55.75^{b}	61.40	55.50	57.40	58.45	59.75	58.50^{bc}
Mean	50.48^{a}	50.41^{a}	50.15^{a}	54.46^{b}	55.00^{b}	-	53.19^{a}	50.03^{a}	53.78^{ab}	55.51^{ab}	57.41^{e}	-
	ISDMD (%)						IVDMD (%)					
0	38.40	40.00	45.00	48.00	52.00	44.68^{a}	45.00	45.00	49.00	52.00	55.00	49.20^{a}
2	45.33	50.45	51.70	60.09	54.94	52.54^{b}	45.50	52.90	51.30	51.05	53.50	50.85^{a}
4	55.33	54.74	51.62	54.72	52.83	53.85^{b}	59.06	45.40	55.10	58.30	59.60	55.49^{b}
6	58.50	55.46	51.27	53.20	58.60	55.41^{b}	62.50	55.00	56.80	58.10	58.90	58.26^{bc}
Mean	49.39^{a}	50.16^{a}	49.89^{a}	54.00^{b}	54.59^{b}	-	53.01^{a}	49.57^{b}	53.05^{a}	54.86^{a}	56.75^{ac}	-

Different superscripts in a row and column are significant ($p<0.01$).
ISOMD - In sacco organic matter digestibility, ISDMD - In sacco dry matter digestibility, IVOMD - In vitro organic matter digetibility, IVDMD - In vitro dry matter digestibility.

Table 3. Significance level of treatment of urea plus lime treated wheat straw on different parameters

Particulars	df	Nutrients									*In sacco* degradability		*In vitro* degradability	
		OM	CP	NDF	ADF	HC	Cellulose	ADL	T. Ash	Silica	DM	OM	DM	OM
Replication	2	0.08	0.04	0.09	0.28	0.71	0.26	0.02	0.07	0.01	10.8	11.18	0.65	1.72
Urea level	4	6.72**	168.2**	60.27**	1.30**	63.43**	3.23**	7.78**	6.92**	1.22**	73.75**	69.99**	56.50**	175.93**
Lime level	3	33.52**	0.10**	112.6**	2.06**	115.2**	1.51**	9.93**	33.78**	2.11**	341.3**	343.7**	172.76**	84.09**
All effect interaction	12	1.14**	0.20**	3.43**	0.88*	3.19**	1.41**	1.46**	1.18**	0.25**	49.75**	45.55**	79.09*	4.52*
Error	38	0.01	0.06	0.34	0.33	0.43	0.27	0.02	0.03	0.03**	9.34	9.71	10.12	0.91

* Significant at $p<0.05$. ** Significant at $p<0.01$.

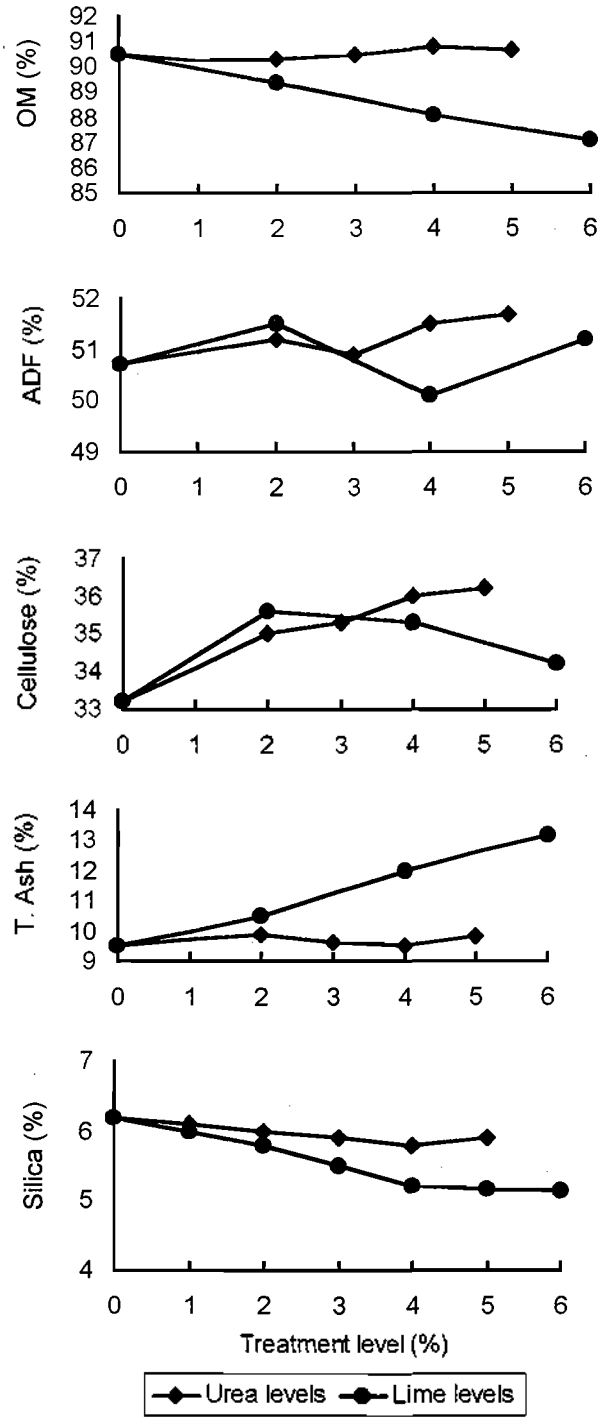

Figure 1. Compositional changes as affected by treatment

different treatment combinations. Alkali treatment had consistently decreased the total cell wall measured as NDF, primarily by solubilzing hemicellulose (Klopfenstein, 1978). Cellulose fibre within the cell wall matrix may be physically restrained from swelling and alkali treatment probably removes these restraints to some extent (Whistler and Teng, 1970). Therefore, such energy producing components like HC and cellulose were made free from lignin which stimulates the solubilization of HC (Rai and Mudgal, 1988). Similar results were also reported by other workers (Oliveros et al., 1993; Sirohi and Rai, 1994, 1995). Ammoniation of straws improves the potential rate and extent of digestion of fibre as an alkali which serves digestion as an essential nutrient for microbes to ensure efficient rumen fermentation (Reddy and Singh, 1992). These results are in agreement with the above reports and possible reason for higher DM and OM digestibilities in wheat straw could be attributed to the swelling effect of cellulose when treated with alkali. Singh (1980) reported an increase in digestibility of DM due to associative effect of urea and lime by 21. 0 units (69.3 vs 48.3%) in comparison with untreated wheat straw. Other workers also reported that urea plus lime treatment was able to increase the digestibility (Sirohi and Rai, 1994, 1995; Zaman and Owen, 1995). Our findings are in accordance with above reports that urea and/or lime treatment of wheat straw in association has potential to solubilize the cell wall matrices and thus their digestibility.

CONCLUSIONS

It is concluded on the basis of present findings that synergistic effect of urea and lime proved to be more effective in increasing the CP content, *in vitro* and *in sacco* digestibilities of DM and OM at optimum level of 4% urea with 4% lime at 50% moisture for 3 wk reaction period.

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