Forage Res., **46** (2) : pp. 157-162 (2020) **http://forageresearch.in**

IMPROVING NUTRITIVE VALUE AND DIGESTIBILITY OF HAY AND CROP RESIDUES

RAJAN KATOCH* AND ANKUR TRIPATHI

Biochemistry Laboratory, Department of Crop Improvement
CSKHPKV, Palampur-176062 (Himachal Pradesh), India
**(e-mail : rajankatoch@yahoo.com)*

(Received : 28 June 2020; Accepted : 10 September 2020)

SUMMARY

The effect of different chemical treatments on nutritional quality and digestibility of wheat straw, rice straw, Sorghum sudan grass (SSG) and Guria grass (*Chrysopogon fulvus*) was investigated. The treatment with sodium chloride (2.00%), aqueous ammonia (10.00%), urea (4.50%) and dilute acid (1.50%) significantly improved the CP content of wheat straw (148.57%), rice straw (66.06%), sorghum sudan grass (SSG) (17.27%) and (30.24%), respectively. Alkali treatments [NaOH (2%) and $Ca(OH)_2$ (0.4g/gm of sample)] were effective in reducing fiber and hemicellulose contents in wheat and rice straws while aqueous ammonia treatment was effective for treatment of SSG and Guria grass. Acid hydrolysis resulted delignification of feeds to the extent of 37.50%. Treatment of rice straw and SSG with sodium chloride resulted 21.62% and 57.58% increase in ash content, respectively. Highest increase in ash content of wheat straw (82.61%) and Guria grass hay (18.30%) was observed with dilute acid and calcium hydroxide treatments, respectively. Alkali treatments resulted significant reduction in phenolic content of straw and hay. The chemical treatments were effective in improving digestibility of fibrous feeds. The results of the study revealed that acid hydrolysis, sodium chloride, sodium hydroxide and aqueous ammonia, treatments had significant effect on improvement in nutritional composition and digestibility of wheat straw, rice straw, SSG and Guria grass hay, respectively.

Keywords : Chemical treatments, digestibility, nutritive quality, delignification

Livestock rearing is an indispensable sector for contributing considerable share in nutritional, environmental and agricultural growth of any country. Presently, India holds largest livestock population in the world and their numbers are continuously increasing (Katoch *et al.*, 2017). Accordingly, the feeding as well as nutritional requirements are also increasing to sustain huge livestock population. This situation has put the available feed resources under tremendous pressure for meeting the requirements of growing livestock population. Intense urbanization and increasing human population is further intensifying the rate of converting farmlands into commercial landscapes (Ayyadurai *et al.*, 2013). At present, the country is under net deficit of 35.60% green fodder, 10.95% dry crop residues and 44% concentrate feeds (IGFRI Vision-2050). According to Ghosh *et al.* (2016), the percentage proportion of fodder unavailability is expected to increase upto 1012 million tonnes of green fodder and 631 million tonnes of dry forage by the year 2050. Therefore, it is obvious that availability of fodder will become the limiting factors in achieving sustainable livestock production in the country. During the periods of unavailability of green fodder, the straws, husks, hay and stover have great significance in livestock feeding (Singh *et al.*, 2013). These are also important for providing comparatively cheap feed source than the commercial feed concentrates. However, the lack of fermentable energy and low protein content with low ruminal digestibility limit their usage as a potential livestock feed.

Wheat (*Triticum aestivum*) and rice (*Oryza sativa*) are the most important cereal crops in mid-Himalayan region. Since, wheat and rice are cultivated traditionally and commercially in this region, the availability of biomass produce is also considerable. Farmers utilize biomass from these crops as a livestock feed when green fodder is unavailable. The high fiber content and the presence of ligno-cellulosic complex, tannin-protein complex and silica in the cell wall are collectively responsible for low quality of these crop residues. SSG (Sorghum Sudan grass) and Guria grass (*Chrysopogon fulvus)* are two important grasses for hay making in mid Himalayan region. The rapid establishment and ease in handling increases the importance of these grasses as a potential livestock feed. Their importance becomes more evident when green fodder is in short supply. Despite of such valuable characteristics, these grasses are not being used as potential livestock feed on a large scale. Since the gap in demand and supply of fodder is continuously increasing, either in term of quality and quantity, it is pertinent to investigate different methods for improving the quality and digestibility of low quality feeds. Keeping this objective under consideration different chemical treatments were investigated for improving nutritional quality and digestibility of high fibrous straw, hay and crop residues.

MATERIALS AND METHODS

Pretreatment of samples : The feed samples were dried at 50°C to the constant weight and ground in a Willey mill (1 mm sieve). Moisture free grounded samples of wheat straw, rice straw and grasses (SSG and Guria grass) and preserved in air tight bags for further analysis.

In alkali treatment, 5gm sample was mixed with 50 ml of sodium hydroxide (2%) and calcium hydroxide (0.4 g/gm of sample in 50 ml of distilled water) solutions for 30 min and 1 hr, respectively at 120°C. For acid hydrolysis, samples were treated with 50 ml of 1.5% sulfuric acid for 3 hrs at 106-108°C. The experimental material was treated with sodium chloride (2%) and urea (4.5%) for overnight and 21 days, respectively at ambient temperature (24-26°C). Treatment of feed resources with ammonium hydroxide (10%) was carried out at 26°C for 24 hrs. Following aqueous ammonia steeping, delignified material was further hydrolyzed with 0.3M of HCl at 100-108°C for 1 hr. After each treatment, the samples were washed, dried and stored in polythene bags for further analysis.

Nutritional analysis : Crude protein (CP) and ash contents were estimated according to the method given in AOAC (2000). Cell wall constituents *i.e.,* Neutral detergent fiber (NDF), Acid detergent fiber (ADF) and Acid detergent lignin (ADL), hemicellulose (HC) and cellulose (CeL) were determined by the method of Goering and Van Soest (1975). The NDF content subtracted from 100 was calculated as cell content (CC). The samples were also analyzed for total carbohydrates (TC) by following the method of Hedge and Hofreiter (1962). Total phenols (TP), simple phenols (SP) and total tannins (TT) were estimated by the method of Makkar (2003). The *in vitro* dry matter digestibility was estimated by two stage digestion method of Tilley and Terry (1963). The significant differences in results were detected by analysis of variance (One-Way ANOVA) together with Duncan's multiple range test (Duncan, 1955). A probability of ≤ 0.05 was selected as criterion for statistically significant difference.

RESULTS AND DISCUSSION

The variations in the level of different nutritional constituents of treated feeds have been presented in Table(s) 1 to 4. To support the growth of gastro-intestinal microflora and increase the nutrient assimilation efficiency of livestock, the protein rich feed resource is of considerable importance (Katoch *et al.*, 2018). The results of the study revealed improvement in CP content in wheat and rice straws from 3.85 to 9.57% and 5.48 to 9.10% after application of different chemical treatments (Table-1 and Table-2). The significant increase (148.57%) in CP content of wheat straw was observed after treatment with sodium chloride, whereas aqueous ammonia and urea treatments resulted 66.06% and 63.86% increase in CP content of rice straw, respectively. It has also been observed that urea treatment (0 to 8%) increases the CP content of maize stover from to the extent of 131% (Oji *et al.*, 2007; Ramirez *et al.*, 2007; Elias and Fulpagare, 2015; Abera *et al.,* 2018). Fadel Elseed (2003) also reported 154% increase in CP content of rice straw treated with 3% ammonia solution. The addition of urea and ammonia to fibrous feeds increases the non-protein nitrogen content which destabilizes the protein complexes with anti-nutrients, thereby improves the CP content (Katoch *et al.,* 2017).

The fiber content (ADF and NDF) in forages has inverse relationship with digestibility of feeds in livestock (Katoch *et al.,* 2017). In the study, highest reduction in NDF content was observed up to 20.35% in wheat straw and 9.08% in rice straw treated with calcium hydroxide and sodium hydroxide, respectively (Table-1 and Table-2). The reduction in NDF content in fibrous feeds may be due to increased solubilization of hemicellulosic fractions in cell wall (Ramirez *et al.,* 2007). The ADF content revealed highest reduction up to 10.34% in wheat straw and 6.73% in rice straw after treatment with dilute sulfuric acid and sodium chloride, respectively (Table-1 and Table-2). Suksombat (2004) also observed 5.62% and 14.35% reduction in ADF and NDF content in rice straw with the application of sodium hydroxide (6%). Casperson *et al.* (2018) reported 14% and 29% reduction in ADF and NDF contents of alkali treated corn stover, respectively. The reduction in fiber content with urea

TABLE 1
Effect of different chemical treatments on nutritional composition of wheat straw

Parameters	Untreated	Urea (4.50%)	Aq. Ammonia (10%)	NaOH (2%)	$Ca(OH)_2$ (0.4g/gm)	NaCl (2%)	Dil. H_2SO_4 (1.50%)
CP (%)	3.85^{e}	6.18^{cd}	6.07^{d}	6.77^{bc}	6.65^{cd}	9.57^{a}	7.35^{b}
TC (%)	7.14^{d}	4.87^{f}	18.35^{a}	11.33^{c}	6.30^{e}	13.86^{b}	13.78^{b}
NDF (%)	82.53^{a}	79.66^{b}	79.73^{b}	67.00^{d}	65.73^{d}	82.06^{a}	73.93^{c}
ADF (%)	51.53^{a}	51.73^{a}	49.33^{b}	49.26^{b}	48.80^{b}	47.27^{c}	46.20^{d}
IVDMD (%)	49.33^{e}	58.27^{a}	56.67^{b}	55.80^{bc}	54.80^{c}	52.67^{d}	54.80^{c}
CC (%)	17.47^{d}	20.34^{c}	20.27^{c}	33.00^{a}	34.27^{a}	17.94^{d}	26.07^{b}
ADL (%)	7.80^{a}	7.06^{b}	6.80^{b}	6.80^{b}	6.73^{b}	6.73^{b}	5.67^{c}
HC (%)	31.00^{b}	27.93^{c}	30.40^{b}	17.74^{d}	16.93^{d}	34.80^{a}	27.73^{c}
CL (%)	43.73^{b}	44.67^{a}	42.53^{c}	42.47^{c}	42.07^{c}	40.53^{d}	40.53^{d}
Ash (%)	2.30^{c}	2.70^{bc}	2.80^{bc}	3.00^{b}	2.67^{bc}	4.13^{a}	4.20^{a}
TP (mg/g)	8.71^{a}	6.99^{cd}	7.33^{bc}	6.96^{cd}	6.72^{cd}	6.35^{d}	7.93^{b}
SP (mg/g)	3.33^{a}	2.94^{b}	2.60^{c}	2.70^{c}	2.26^{d}	1.90^{e}	2.33^{d}
TT (mg/g)	5.38^{ab}	4.05^{c}	4.73^{bc}	4.26^{c}	4.46^{c}	4.45^{c}	5.60^{a}

TABLE 2
Effect of different chemical treatments on nutritional composition of rice straw

Parameters	Untreated	Urea (4.50%)	Aq. Ammonia (10%)	NaOH (2%)	$Ca(OH)_2$ (0.4g/gm)	NaCl (2%)	Dil. H_2SO_4 (1.50%)
CP (%)	5.48^{c}	8.98^{a}	9.10^{a}	7.35^{b}	5.72^{c}	7.35b	6.07^{c}
TC (%)	6.87^{d}	8.57^{c}	6.11^{de}	6.08^{de}	4.72^{e}	10.80^{b}	12.35^{a}
NDF (%)	76.40^{a}	77.93^{a}	77.20^{a}	69.46^{d}	71.00^{c}	70.26^{cd}	72.86^{b}
ADF (%)	48.60^{b}	49.40^{a}	46.53^{d}	46.46^{d}	47.53^{c}	45.33^{e}	45.60^{e}
IVDMD (%)	45.67^{d}	56.20^{a}	56.07^{a}	54.13^{b}	55.47^{ab}	52.07^{c}	53.80^{bc}
CC (%)	23.60^{d}	22.07^{d}	22.80^{d}	30.54^{a}	29.00^{b}	29.74^{ab}	27.14^{c}
ADL (%)	4.80^{a}	4.20^{b}	4.20^{b}	4.00^{b}	3.47^{c}	3.47^{c}	3.00^{d}
HC (%)	27.80^{b}	28.53^{b}	30.67^{a}	23.00^{d}	23.47^{cd}	24.93^{c}	27.26^{b}
CL (%)	43.80^{b}	45.20^{a}	42.33^{c}	42.46^{c}	44.06^{b}	41.86^{c}	42.60^{c}
Ash (%)	7.40^{d}	8.60^{abc}	8.80^{ab}	8.30^{bc}	8.00^{cd}	9.00^{a}	6.40^{e}
TP (mg/g)	6.63^{a}	6.02^{b}	6.27^{ab}	5.13^{c}	3.57^{e}	4.15^{d}	5.46^{ac}
SP (mg/g)	2.54^{b}	2.90^{a}	2.02^{c}	1.95^{c}	1.35^{d}	2.00^{c}	1.90^{c}
TT (mg/g)	4.08^{ab}	3.12^{c}	4.25^{a}	3.17^{c}	2.22^{d}	2.15^{d}	3.56^{bc}

and alkali treatment in fibrous feeds may be due to breakage of ester bonds of uronic acids in hemicelluloses (Rodriguez *et al.*, 2002; Ramirez *et al.*, 2007). Klopfenstein *et al.* (1972) reported 7.30% decrease of ADF content in maize stover treated with sodium hydroxide (5%). Treatment of wheat and rice straw with dilute sulfuric acid resulted reduction in ADL content up to 27.31 and 37.50%, respectively. Chen *et al.* (2009) also recorded 12.20% reduction in lignin content of maize stover after treatment with dilute sulfuric acid (1.50%). The degradation rate of hemicellulose content in wheat and rice straws treated with calcium hydroxide and sodium hydroxide was significantly high than that of other treatments, whereas treatment with urea caused significant increase in cellulose content. This is mainly due to the cleavage of alkali labile linkages between lignin and structural polysaccharides (Buettner *et al.*, 1982). Ammoniation of feed sources with urea also results in swelling and increased flexibility of fiber (Saenger *et al.*, 1982).

Cell content is an important forage quality parameter mainly associated with total soluble carbohydrates or non structural carbohydrates. In this study, alkali treatments were effective in increasing cell content in rice straw and wheat straw (Table-1 and Table-2). Chen *et al.*, (2009) reported that lime treatment hydrolyzed 14.80% of hemicellulose into soluble sugar in corn stover. The level of total carbohydrates in wheat straw was increase significantly (157%) with ammonia treatment which ultimately increases the digestibility and preservative quality of feeds by inhibiting the mould growth (Abou-EL-Enin *et al.*, 1999). Treatment with dilute sulfuric acid significantly increased (79.77%) the level of total carbohydrates in rice straw.

Ash content of feed resources represents total mineral constituents of feed (Katoch *et al.*, 2018). The concentration of minerals in forages depends on interaction among number of soil and plant factors (McDowell 2003). Among various chemical treatments, the maximum increase in ash content of wheat (82.61%) and rice straw (21.62%) was observed with dilute sulfuric acid and sodium chloride treatment, respectively (Table 1 and Table 2).

Phenolics and tannins are important anti-nutritional factors in forages, which inhibit coarse fodder digestion, inhibit the action of fibrolytic microorganisms and reduce the growth of ruminal microflora which ultimately affect digestibility and absorption of nutrients from feeds. Total phenolics content reduced significantly to 27.10% in wheat straw

TABLE 3
Effect of different chemical treatments on nutritional composition of sorghum sudan grass (SSG)

Parameters	Untreated	Urea (4.50%)	Aq. Ammonia (10%)	NaOH (2%)	$Ca(OH)_2$ (0.4g/gm)	NaCl (2%)	Dil. H_2SO_4 (1.50%)
CP (%)	15.52[b]	18.20[a]	17.77[a]	11.55[c]	9.80[d]	10.15[d]	18.08[a]
TC (%)	9.10[b]	3.66[d]	8.12[bc]	14.99[a]	1.96[e]	6.72[c]	7.70[bc]
NDF (%)	53.93[a]	44.80[e]	42.66[f]	45.86[d]	48.80[c]	51.87[b]	42.73[f]
ADF (%)	34.93[a]	34.93[a]	33.06[b]	32.60[bc]	32.47[bc]	32.20[c]	31.40[d]
IVDMD (%)	54.67[b]	58.07[a]	56.53[ab]	58.13[a]	59.07[a]	58.07[a]	57.80[a]
CC (%)	46.07[f]	55.20[b]	57.34[a]	54.13[c]	51.20[d]	48.13[e]	57.27[a]
ADL (%)	5.80[a]	5.27[b]	5.00[b]	4.87[bc]	5.20[b]	5.00[d]	4.53[c]
HC (%)	19.00[a]	9.87[e]	9.60[e]	13.26[c]	16.33[b]	19.67[a]	11.33[d]
CL (%)	29.13[a]	29.66[a]	28.06[b]	27.73[bc]	27.27[bc]	27.20[bc]	26.87[c]
Ash (%)	3.30[e]	4.50[b]	3.73[cd]	4.80[b]	4.00[c]	5.20[a]	3.40[de]
TP (mg/g)	15.13[a]	7.04[e]	10.19[c]	4.18[f]	6.77[e]	12.01[b]	7.79[d]
SP (mg/g)	7.32[a]	2.26[f]	2.50[e]	2.53[e]	3.98[d]	6.09[b]	5.65[c]
TT (mg/g)	7.81[a]	4.78[c]	7.69[a]	1.65[e]	2.78[d]	5.92[b]	2.14[e]

TABLE 4
Effect of different chemical treatments on nutritional composition of Guria grass

Parameters	Untreated	Urea (4.50%)	Aq. Ammonia (10%)	NaOH (2%)	$Ca(OH)_2$ (0.4g/gm)	NaCl (2%)	Dil. H_2SO_4 (1.50%)
CP (%)	12.60[c]	14.58[b]	15.37[b]	9.45[d]	9.10[d]	7.12[e]	16.41[a]
TC (%)	10.76[d]	2.41[g]	16.84[a]	13.97[b]	6.23[f]	7.49[e]	13.29[c]
NDF (%)	50.93[a]	46.33[cd]	39.60[f]	42.66[e]	46.73[c]	48.80[b]	45.73[d]
ADF (%)	34.73[a]	34.20[ab]	32.73[b]	33.33[ab]	33.40[ab]	32.87[ab]	30.47[c]
IVDMD (%)	50.53[c]	56.53[ab]	58.80[a]	58.07[ab]	56.40[ab]	55.87[b]	57.33[ab]
CC (%)	49.06[f]	53.67[cd]	60.40[a]	57.33[b]	53.27[d]	51.20[e]	54.27[c]
ADL (%)	6.53[a]	6.06[b]	5.73[bc]	5.87[bc]	5.53[c]	5.67[bc]	5.47[c]
HC (%)	16.20[a]	12.13[c]	6.87[e]	9.33[d]	13.20[bc]	15.93[a]	15.26[ab]
CL (%)	28.20[a]	28.14[a]	27.00[a]	27.46[a]	27.87[a]	27.20[a]	25.00[b]
Ash (%)	4.70	5.00	5.04	5.07	5.56	5.00	5.50
TP (mg/g)	5.56[a]	4.64[b]	4.35[bc]	2.88[d]	4.13[c]	4.36[bc]	5.39[a]
SP (mg/g)	4.21[b]	2.49[d]	2.17[e]	2.73[c]	2.78[c]	2.24[e]	4.70[a]
TT (mg/g)	1.35[b]	2.15[a]	2.18[a]	0.15[d]	1.35[b]	2.12[a]	0.69[c]

In table(s) 1 to 4, each value represents mean of three replications. In the same row, significant differences according to CRD are indicated by different alphabets. Superscripts represent significant values at ($P \leq 0.05$). Same alphabets represent that their values are statistically at par ($P \leq 0.05$).

and 46.15% in rice straw treated with sodium chloride and calcium hydroxide, respectively (Table 1 and Table-2). In case of simple phenols, sodium chloride treatment reduced up to 42.94% in wheat straw, whereas 46.85% reduction was observed with calcium hydroxide treatment in rice straw (Table 1 and Table-2). Wheat straw treated with urea and rice straw with sodium chloride revealed maximum significant reduction in total tannin content from 5.38 to 4.05% and from 4.08 to 2.15%, respectively.

For the success of any livestock production programme, inclusion of highly digestible feed in livestock feeding is of paramount importance. In the present study, all chemicals treatments revealed increase in digestibility of wheat straw and rice straw. Among the treatments, the highest percentage increase in digestibility of wheat straw (from 49.33 to 58.27%) and rice straw (from 45.67 to 56.20%) was observed with urea treatment (Table 1 and Table 2). Shen *et al*. (1998) reported that urea treatment releases the free phenolic group from the cell wall matrix that improves the straw digestibility. Oji *et al*. (2007) reported 15.30% increase in digestibility of urea treated corn husks.

The effect of different chemical treatments on nutritional quality and digestibility of sorghum sudan grass and Guria grass is presented Table-3 and Table-4. Application of urea, aqueous ammonia and dilute sulfuric acid revealed significant increase, whereas alkali and salt treatments revealed reduction in CP content of SSG and Guria grass. The highest increment in CP content of SSG and Guria grass was observed with urea (from 15.52 to 18.20%) and acid treatments (from 12.60 to 16.41%), respectively. The significant increase in CP content by urea treatment may be result of two processes: a) conversion of urea into ammonia by urease enzyme b) effect of ammonia on cell wall constituents (Katoch *et al.*, 2017). The reduction in CP content of treated SSG and Guria grass might be due to leaching of protein after washing of treated samples. Aqueous ammonia treatment revealed maximum significant reduction in NDF content from 53.93 to 42.66% in SSG and from 50.93 to 39.60% in Guria grass. The dilute acid treatment revealed maximum significant decrease in ADF content from 34.93 to 31.40% and from 34.73 to 30.47%, in SSG and Guria grass, respectively. With all chemical treatments, the ADL content reduced significantly in SSG and Guria grass. The highest reduction in ADL content of both the grasses was revealed by dilute sulfuric acid treatment. Except sodium chloride and urea treatments, the other chemical treatments resulted reduction in hemicellulose and cellulose content of SSG whereas, in Guria grass, the hemicellulose and cellulose content reduced significantly with all chemical treatments. The highest reduction in hemicellulose and cellulose content of Guria grass was observed with aqueous ammonia and acid treatments, respectively. The maximum increase in ash content of SSG and Guria grass was exhibited by sodium chloride treatment (from 3.30 to 5.20%) and calcium hydroxide treatment (form 4.70 to 5.56%). The chemical treatments of grasses revealed variable effects on total carbohydrate content. In SSG, the maximum significant increment (64.73%) in the level of total carbohydrates was observed with sodium hydroxide treatment, whereas the aqueous ammonia treatment revealed 56.51% increase in total carbohydrates of Guria grass. The increase in total carbohydrates might be due to breakdown of complex polysaccharides into simpler units and reduction may be attributed to their leaching after washing of samples. Treatment of grasses with sodium hydroxide was promising in reducing the phenolic and tannin content as compared to other treatments. The dry matter digestibility of grasses was significantly improved with all chemical treatments. The highest significant increase in digestibility of SSG (54.67 to 59.07%) and Guria grass (50.53 to 58.80%) was observed with calcium hydroxide and aqueous ammonia treatments, respectively.

CONCLUSION

The study unveiled the significant effect of different chemical treatments on nutritional composition and digestibility of fibrous feeds understudy. The improvement in the feeding value of feed resources with different chemical treatments may be attributed to alterations in nitrogen content and breakage of bonds holding the structure of fiber and other complexes. The cumulative grading analysis revealed that acid hydrolysis, sodium chloride, sodium hydroxide and aqueous ammonia treatments were promising for improving quality and digestibility of wheat straw, rice straw, SSG and Guria grass, respectively. Further studies are proposed for the validation of effect of these treatments on animal health and productivity.

REFERENCES

Abera, F., M. Urge and G. Animut, 2018 : Feeding value of maize stover treated with urea or urea molasses for hararghe highland sheep. *Open Agri. J.,* **12**: 84-94.

Abou-El-Enin, O.H., J.G. Fadel and D.J. Mackill, 1999 : Differences in chemical composition and fibre digestion of rice straw with, and without, anhydrous ammonia from 53 rice varieties. *Anim. Feed Sci. Technol.,* **79**:129–136

AOAC, 2000 : Official Methods of Analysis of the Association of Official Analytical Chemists. 17th ed. Gaithersburg, Maryland, USA.

Ayyadurai, P., R. SathyaPriya, N. Jegathjothi, and J. Gokila. 2013 : A review on optimizing forage quality through management. *Int. J. Agric. Sci. Res.*, 3: 173-180.

Buettner, M. R., V. L. Lechtenberg, K. S. Hendrix and J. M. Hertel, 1982 : Composition and digestion of ammoniated tall fescue (*Festuca arundinacea* Schreb) hay. *J. Anim. Sci.,* **54**:173-178.

Casperson, B. A., A. E. Wertz-Lutz, J. L. Dunn and S. S. Donkin, 2018 : Inclusion of calcium hydroxide-treated corn stover as a partial forage replacement in diets for lactating dairy cows. *J. Dairy Sci.,* **3**: 2027-2036.

Chen, M., J. Zhao and L. Xia. 2009: Comparison of four different chemical pretreatments of corn stover for enhancing enzymatic digestibility. *Biomass and Bioenergy*, 33: 1381-1385.

Duncan, D. B., 1955: Multiple range and multiple F- test. *Biometrics*, **11**: 1-5

Elias, S. T., and Y. G. Fulpagare, 2015 : Effects of urea treated maize stover silage on growth performance of crossbred heifers. J. *Agric. Vet. Sci.,* **8**: 58-62.

Fadel Elseed, A. M. A., J. Sekine, M. Hishinuma and K. Hamana, 2003 : Effects of ammonia, urea plus calcium hydroxide and animal urine treatments on chemical composition and *in sacco* degradability of rice straw. *Asian-Austral. J Anim. Sci.,* **16**: 368-373.

Ghosh, P.K., D.R. Palsaniya, and R. Srinivasan, 2016 : Forage Research in India: Issues and strategies. *Agric. Res. J.,* **53**: 1-12.

Goering, H. D., and P. J. Van Soest, 1975 : Forage fibre analysis, U.S. Dept. of Agriculture, Washington DC.

Hedge, J. E., and B. T. Hofreiter, 1962 : In: Carbohydrates Chemistry, 17th edition (RL Whistler and JN BeMiller) Academic Press, New York.

IGFRI Vision, 2050 : Indian Grassland and Fodder Research Institute, Jhansi (U.P.), India.

Katoch, R., Apoorva, A. Tripathi and S. Sood, 2017 : Improving nutritive value and digestibility of maize stover - A review. *Forage Res.,* **43**:174-180.

Katoch, R., A. Tripathi and N. Thakur, 2018 : Comparative analysis of three *Rumex* species for livestock feeding prevailing under mid-Himalayan Region. *Indian J. Agric. Biochem.,* **31**: 181-185.

Klopfenstein, T. J., V. E. Krause, M. J. Jones and W. Walter, 1972: Chemical treatment of low quality roughages. *J. Anim. Sci.,* **35**: 418-422.

Makkar, H. P. S., 2003 : Quantification of tannins in tree and shrub foliage: A laboratory manual. Kluwer Academic Publishers, Sordrecht, The Netherlands, pp 43-54.

McDowell, L. R., 2003 : Minerals in animal and Human Nutrition. 2nd edn., Elsevier, Netherlands, 256-315.

Oji, U. I., H. E. Etim and F. C. Okoye, 2007: Effects of urea and aqueous ammonia treatment on the composition and nutritive value of maize residues. *Small Rumin. Res.,* **69**: 232-236.

Ramirez, G. R., J. C. Aguilera-Gonzalez, G. Garcia-Diaz, and A. M. Nunez-Gonzalez, 2007 : Effect of urea treatment on chemical composition and digestion of *Cenchrus ciliaris* and *Cynanodon dactylon* Hays and *Zea mays* residues. *J. Anim. Vet. Adv.,* **6**: 1036-1041.

Rodriguez, N., O, Arauho-Febres, B.Y. Gonzalez and J. Vergara, 2002 : Urea ammonification effect on cell wall components of *Brachiaria humidicola* (Rendle) Schweick hay at different cutting ages. *Arch. Latinoam. Prod. Anim.* **10**: 7-13.

Saenger, P. F., R. P. Lemenager and K. S. Hendrix, 1982 : Anhydrous ammonia treatment of corn stover and its effects on digestibility, intake and performance of beef cattle. *J. Anim. Sci.,* **54**: 419-425.

Shen, H. S., D. B. Ni, and F. Sundstol, 1998: Studies on untreated and urea-treated rice straw from three cultivation seasons: 1. Physical and chemical measurements in straw and straw fractions. *Anim. Feed Sci. Technol.,* **73**: 243-261.

Singh, K. M., R. K. P. Singh, A. K. Jha and A. Kumar, 2013: Fodder marketing in Bihar: An exploratory study. *Econ. Aff.,* **58**: 355-364.

Suksombat, W., 2004 : Comparison of different alkali treatment of bagasse and rice straw. *Asian-Australas. J. Anim. Sci.,* **17**: 1430-1433.

Tilley, J. M. A., and R. A. Terry, 1963 : A two-staged technique for the *in-vitro* digestion of forage crops. *J. Br. Grassl. Soc.,* **18**: 104-111.