PJN
ISSN 1680-5194

Pakistan Journal of Nutrition

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

Pakistan Journal of Nutrition 11 (12): 1146-1151, 2012
ISSN 1680-5194

Effect of Urea Treatment on the Chemical Composition and Rumen Degradability of Groundnut Hull

A.A. Abdel Hameed[1], M.A. Salih[2] and Fedel EL Seed[2]
[1]University of Dongola, Faculty of Agricultural Sciences, Sudan
[2]University of Khartoum, Faculty of Animal Production, Khartoum, Sudan

Abstract: The objective of this study was to evaluate the chemical composition and rumen degradability of Groundnut Hull (GH) treated with three levels of urea (2, 4 and 6%) and ensiled in plastic bags for three periods (2, 4 and 6 weeks). Data were analyzed in completely randomized design with factorial; with ensiled period and urea level are the main factors. Degradability of treated groundnut hull was carried out in three fistulated steers. Urea treatment and ensiling periods increased CP content of the GH significantly (p<0 .05) and ranked as follows 7.81, 10.22 and 10.24% for 2, 4 and 6% urea level ensiled for 2, 4 or 6 weeks respectively. However, these increments in CP contents were found between urea levels but not between periods of treatment. All ensiling periods were interacted significantly with urea level. NDF content was decreased (p<0.05) from 87.8 for UGH to 84.6, 72.5 and 74.2% for 2, 4 and 6% urea level ensiled for 2, 4 or 6 weeks respectively. ADF and ADL contents were significantly (p< 0.05) decreased for treated GH compared to untreated GH. Degradability of DM, OM and NDF were increased (P<0.05) significantly with increasing urea level treatment. Four and 6% urea level had a higher potential degradability values compared with 2% urea level. Ensiling periods resulted in significant differences between urea treatment levels. However, no differences were found within the same level. This study indicated that, chemical composition and degradability of GH would be improved by increases urea level and ensiling periods.

Key words: Chemical composition, rumen degradation, urea treatment, ensiled periods, groundnut hull

INTRODUCTION

Sudan is largest country in Africa with great agricultural potential in general and livestock in particular. The population of cattle, sheep, goat and camel were around 132 million head (Ministry of Agriculture, 2008). More than 90% of the livestock in Sudan are kept in nomadic flocks for meat, milk and skins under extensive system depending mainly on rangeland resources, a system which has always been faced by many obstacles towards the establishment of proper animal production industry. Recently crop production activities has grown considerably taken in large areas of grazing land in semi arid zone which represents the main zone for livestock keeping. More than 15 million feddans are now under cultivation. This situation of reduction of grazing pasture and expansion of cultivation land necessitates the finding of some kind of integration between animal and crop production through the inclusion of agricultural by-product residues in animal feed.

A survey indicate that, more than 7 million tones of residues and by-product were produced annually over the last 4 years (Ministry of Agriculture, 2008), consisting of groundnut hulls and hulums, cereal straw (sorghum and wheat), sugar-cane (tops and baggasse) and oil seeds cakes of cotton, sesame and groundnut. The major biological constraints for using poor quality roughages is related to the low crude protein and low accessibility of cell-wall polysaccharides by both cell-free and microbial enzymes and this often results in low voluntary intake (Preston and Leng, 1987).

Ammoniation method, using ammonia gas and ammonium hydroxide to improve the digestibility of fibrous roughages is now an accepted techniques (Sundstol and Owen, 1984; Orden *et al.*, 2000). Despite the large quantities of poor quality roughages available for ammoniation in developing countries, commercial application of this approach has so far been limited mainly to developed countries because of technical and economical constraints in the former. Therefore, utilization of urea to improve the digestibility of fibrous roughages is more useful because it's applicable, cheaper and safer. Therefore, the Objective of this study was enhancing the nutritive value and utilization of groundnut hulls by urea treatments.

MATERIALS AND METHODS

Preparation of treated groundnut hulls: A quantity of 27 kg of groundnut hulls were treated with three different levels of urea 2, 4 or 6%. Urea were dissolved in water (1L/kg DM), thoroughly mixed and the air removed from each sack (1 kg treated groundnut hulls / sack). The sacks were tightly sealed and stored in the shade fore a

Corresponding Author: A.A. Abdel Hameed, University of Dongola, Faculty of Agricultural Sciences, Sudan

period of 2, 4 or 6 weeks for each treatment. After the curing period the treated groundnut hull was spread on polyethylene sheet for 1 day to allow the evaporation of access ammonia.
Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) were analyzed according to Goering and Van Soest (1970). CP content was determined according to (AOAC, 1995).

Degradability study: Degradability studies of treated groundnut hulls were carried out in three fistulated steers according to the nylon bag technique described by Ørskov *et al.* (1980). The steers were fed at maintenance level on a balanced roughage-concentrate diet with free access to water and mineral blocks. Five g of each sample were put in the bag (80×140 mm; pore, size 45μ), tied with nylon ribbon and incubated for 4, 8, 16, 24, 48, 72 and 96hrs. At the end of each period of time the bags were immediately removed and put in a cold water to stop the rumen microorganism activity then washed under tap water. The dry matter disappearance at zero time (soluble fraction) was estimated as washing loss of sample weighed into the nylon bag and rinsed through running tab water. The residues in the bags were oven dried at 105°C for overnight, cooled in desiccators and weighed. Dry residues in the bags were calculated, the percentage of dry matter loss was calculated as follows:

$$\frac{\text{Wt. of sample incubated} - \text{Wt. of residues}}{\text{Wt. of sample incubated}} \times 100$$

Residual samples after incubation were mixed, pooled and made ready for analysis; the degradation kinetics of the incubated sample may be described by curve linear regression of CP loss from the bag with time:

$$P = a+b\,[1- e^{ct}]$$

Where

P : Potential degradability
a : Axis intercept at time zero represent soluble and completely degraded substrate that is rapidly washed out of the bag
b : The difference between the intercept (a) and asymptote, represent insoluble but potentiality degradable substrate which is degraded by microorganism according first order kinetic
t : Incubation time
c : Constant rate

$$\text{Effective degradability} = a + \left[\frac{bc}{c+k}\right]$$

where, a, b and c are constants as defined in Eq. 1
k = Rumen sample particles out flow rate.

Then a graph was plotted by the fitted values of CP disappearance% against time of incubation in hours to form a curve

Chemical analysis: Samples of treated and untreated groundnut hull were analyzed for their crude protein content according to (AOAC, 1990). NDF, ADF and ADL were determined according to Georing and Van Soest (1970).

Statistical analysis: Data were analyzed by analysis of variance for completely randomized design (Steel and Torrie, 1980). Where the F test was significant, the treatment means were compared using Least Significant Difference (LSD).
The result from in-situ study fitted to model p = a+b(1-e ct) of Orskov and McDonald (1979) to determine the degradation characteristics of the incubated samples.

RESULTS

General appearance: Physical changes in the treated groundnut hulls were quite obvious after 2, 4 or 6 weeks of ensiling in stacks using 2, 4 or 6% urea. Strong smell of excess ammonia was evident when uncovering the stacks. The color of the treated hulls turned brown. It acquired a soft texture, reduced dustiness, mould free and was much easier to handle than untreated hulls.

Compositional changes: Table 1 showed the chemical analysis of untreated (UGH) and urea Treated Groundnut Hulls (TGH). Results showed low contents of protein (4.54% CP) with a high contents of cells wall (87.8% NDF) (38.4% ADL) and (74.2% ADF) in the (UGH). However, when 2, 4, or 6% level of urea were added and ensiled for 2, 4 or 6 weeks, the CP contents increased while cells wall diminished significantly ($p<0.05$) in all the treatments. Among the TGH there were a significant ($p<0.05$) differences in CP content between treatments; whereas, the increased in CP content was greater with 6% urea (10.89%) and 4% urea (10.70%) compared with 2% (8.13%) urea treatments. No differences were found in CP contents at the same level of urea due to ensiling periods of time. There was a significant ($p<0.05$) differences in NDF contents between UGH and TGH. Ensiling of groundnut hulls with urea was resulted in reduction of NDF contents of groundnut hulls by 4.8, 17.08 and 15.35% for (2% urea×2 weeks) (4% urea×4 weeks) and (6% urea×6 weeks), respectively. However, 4% urea with 6 weeks had a lower value 70.53% but not significant compared with 73.64 and significant with 82.14% for 6% urea with 6 weeks and 2% urea with 2 weeks respectively. ADL and ADF contents of groundnut hulls were significantly ($p<0.05$) decreased with increasing urea treatments and ensiling periods. The decrease in ADL and ADF was greatest when the urea level and ensiling period were

Table 1: CP, NDF, ADL and ADF contents of untreated and urea treated (2, 4 and 6%) groundnut hull, ensiled for 2, 4 and 6 weeks

Urea level (% DM)	Ensiling period (Weeks)	CP	NDF	ADL	ADF
0	0	4.54	87.80	38.40	74.20
2	2	8.13^{a}	84.61^{a}	34.98^{a}	70.86^{a}
2	4	7.58^{b}	82.14^{a}	30.7^{b}	69.24^{ab}
2	6	7.72^{b}	84.00^{a}	30.17^{b}	68.11^{abc}
4	2	10.70^{a}	72.94^{b}	27.08^{c}	64.44^{d}
4	4	9.85^{a}	74.93^{b}	26.36^{c}	66.95^{bcd}
4	6	10.12^{a}	70.53^{b}	25.54^{cd}	65.99^{bca}
6	2	10.01^{a}	75.54^{b}	26.39^{c}	65.55^{cd}
6	4	9.82^{a}	73.79^{b}	25.22^{cd}	66.90^{bcd}
6	6	10.89^{a}	73.64^{b}	23.60^{d}	65.61^{cd}
SEM		0.491	3.23	0.9797	1.65

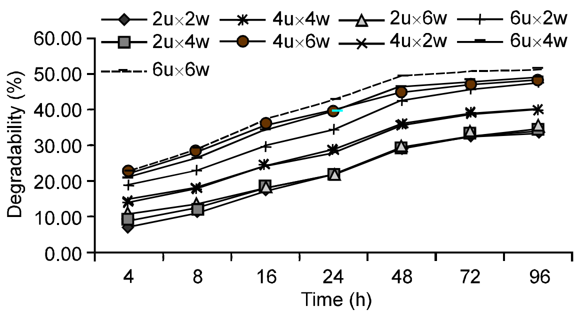

Fig. 1: Rumen degradation of DM degradability (%) of urea treated (2, 4 and 6%) groundnut hull, ensiled for 2, 4 and 6 weeks, u = urea level (%) and w = ensiling periods/weeks

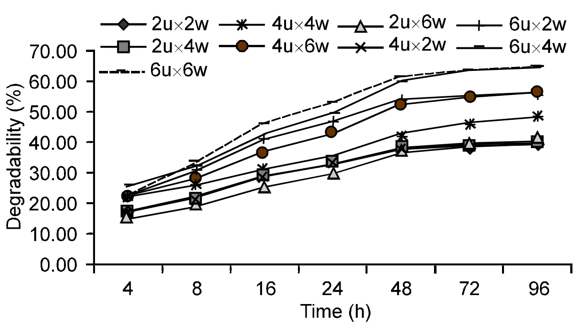

Fig. 2: Rumen degradation of OM (%) of urea treated (2, 4 and 6%) groundnut hull, ensiled for 2, 4 and 6 weeks. u = urea level (%) and w = ensiling periods/weeks

both high, under which conditions the maximum value of reduction (38.54%) and (11.66%) occurred for ADL and ADF respectively.

***In-situ* degradability:** Average proportion of DM, OM and NDF disappearing from urea treated groundnut hulls were plotted graphically in Fig. (1-3).

The degradation characteristics of dry matter in the rumen: The soluble fraction (a), Potential Degradability (PD) and the effective degradability in the different rate of outflow showed significant difference (P>0.05), while the

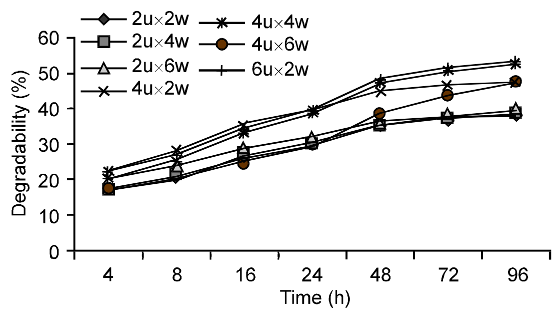

Fig. 3: Rumen degradation of NDF (%) of urea treated (2, 4 and 6%) groundnut hull, ensiled for 2, 4 and 6 weeks. u = urea level (%) and w = ensiling periods/weeks

rate of degradation (fraction c) showed no significant differences (P>0.05) among all treatments and times. Although, no differences were found between 4% urea treatment × 6 weeks and 6% urea treatments (Table 2). The degradation rate of dry matter tended to be greater in the first 24 h than that in the latter period of incubation for all the treatments.

The degradation characteristics of organic matter in the rumen: The rate of degradation (fraction c) showed no significant difference (P>0.05) among all treatments and times. whereas, the soluble fraction (a), slow degradable fraction (b), Potential Degradability (PD) and the effective degradability in different rate of outflow showed a significant difference (P>0.05) among all treatments and times (Table 3), fig (3). The degradable fraction of OM was significantly (P>0.05) increased for 6 and 4 compared with 2% urea level treatments. The interaction effect between urea level and treatment periods showed no significant difference.

The degradation characteristics of neutral detergent fiber in the rumen: The soluble fraction (a) and rate of degradation (fraction c) showed no significant difference (P>0.05), while Potential Degradability (PD) and the effective degradability in the rate of 2, 5 and 8% outflow showed significant (P>0.05) difference among all treatments and times (Table 4).

Table 2: DM degradability kinetics of urea treated (2, 4 and 6%) groundnut hull, ensiled for 2, 4 and 6 weeks

						ED		
Treat	Time	a	b	c	PD	2%	5%	8%
2	2	2.60^{e}	31.77^{bc}	0.04^{ab}	34.37^{c}	23.50^{d}	16.53^{d}	13.17^{d}
2	4	5.30^{de}	30.23^{c}	0.04^{ab}	35.53^{c}	24.13^{d}	17.47^{d}	14.40^{d}
2	6	7.97^{cd}	29.30^{c}	0.04^{ab}	37.27^{c}	24.63^{d}	18.13^{d}	15.37^{d}
4	2	11.13^{ab}	30.40^{c}	0.04^{ab}	41.53^{b}	30.20^{c}	23.50^{c}	20.30^{c}
4	4	9.33^{bcd}	31.40^{bc}	0.04^{ab}	40.73^{b}	30.33^{c}	23.46^{c}	20.00^{c}
4	6	13.40^{ab}	36.90^{a}	0.07^{a}	50.30^{a}	39.60^{a}	32.90^{a}	29.17^{a}
6	2	13.47^{ab}	35.50^{a}	0.04^{ab}	49.00^{a}	36.40^{b}	28.77^{b}	25.03^{b}
6	4	14.40^{a}	37.00^{a}	0.06^{ab}	51.40^{a}	42.30^{a}	34.97^{a}	30.80^{a}
6	6	14.07^{ab}	34.80^{ab}	0.06^{ab}	48.90^{a}	39.43^{ab}	32.20^{a}	28.17^{a}
	SEM	2.32	1.75	0.02	1.62	1.50	1.53	1.26

(a): Readily degradable fraction; (b): Slow degradable fraction; (c): Rate of degradable fraction; (PD): Potential degradability; (ED): Effective degradability; (SEM): Standard Error of The Mean; a-b means with different superscript in the same column were significantly different ($P < 0.05$). treat: urea level treatment (%), time: ensiling period (week)

Table 3: OM degradability kinetics of urea treated (2, 4 and 6%) groundnut hull, ensiled for 2, 4 and 6 weeks

						ED		
Treat	Time	a	b	c	PD	2%	5%	8%
2	2	9.57^{d}	29.27^{d}	0.07^{a}	38.83^{c}	32.33^{de}	26.70^{d}	23.37^{cd}
2	4	10.60^{d}	29.87^{d}	0.06^{ab}	40.43^{c}	32.63^{de}	26.63^{d}	23.30^{cd}
2	6	9.43^{d}	30.17^{d}	0.05^{ab}	39.67^{c}	30.63^{e}	26.10^{d}	20.63^{d}
4	2	11.73^{cd}	28.33^{d}	0.06^{ab}	40.07^{c}	32.67^{de}	26.90^{d}	23.73^{cd}
4	4	18.43^{a}	31.80^{cd}	0.03^{b}	50.17^{b}	37.73^{d}	30.77^{c}	27.50^{Bc}
4	6	15.50^{ab}	41.47^{bc}	0.05^{ab}	56.97^{b}	44.30^{c}	35.30^{b}	30.63^{ab}
6	2	17.27^{ab}	43.73^{b}	0.07^{ab}	55.93^{b}	46.10^{b}	38.00^{ab}	33.33^{a}
6	4	16.93^{ab}	48.20^{ab}	0.05^{ab}	65.13^{a}	50.80^{a}	40.43^{ab}	34.93^{a}
6	6	17.93^{ab}	58.73^{a}	0.08^{a}	65.37^{a}	52.03^{a}	41.50^{a}	35.43^{a}
	SEM	2.25	5.36	00.02	3.39	2.78	2.66	2.46

(a): Readily degradable fraction; (b): Slow degradable fraction; (c): Rate of degradable fraction; (PD): Potential degradability; (ED): Effective degradability; (SEM): Standard Error of The Mean;a-b means with different superscript in the same column were significantly different ($P<0.05$)

Table 4: NDF degradability kinetics of urea treated (2, 4 and 6%) groundnut hull, ensiled for 2, 4 and 6 weeks.

						ED		
Treat	Time	a	b	c	PD	2%	5%	8%
2	2	11.97^{ab}	27.20^{bc}	0.06^{ab}	39.13^{c}	31.17^{bc}	25.67^{cd}	22.80^{bc}
2	4	12.33^{ab}	28.40^{bc}	0.05^{ab}	41.23^{bc}	31.17^{bc}	25.37^{cd}	22.53^{bc}
2	6	16.50^{ab}	22.00^{c}	0.05^{ab}	38.50^{c}	32.40^{b}	27.80^{bc}	25.30^{ab}
4	2	13.60^{b}	28.40^{bc}	0.03^{ab}	39.00^{c}	27.53^{c}	21.33^{d}	18.50^{c}
4	4	14.37^{ab}	33.77^{ab}	0.07^{a}	48.13^{ab}	39.63^{a}	33.20^{a}	29.53^{a}
4	6	13.53^{ab}	41.70^{a}	0.05^{ab}	55.27^{a}	40.90^{a}	32.67^{ab}	28.73^{a}
6	2	14.00^{ab}	40.77^{a}	0.02^{b}	54.80^{a}	33.90^{b}	25.63^{cd}	22.23^{bc}
6	4	12.73^{ab}	39.63^{a}	0.04^{ab}	52.37^{a}	38.37^{a}	29.63^{abc}	25.37^{ab}
6	6	17.07^{a}	38.10^{a}	0.04^{ab}	55.167^{a}	41.87^{a}	33.57^{a}	29.47^{a}
	SEM	2.99	4.32	0.02	3.61	1.99	2.36	2.32

(a): Readily degradable fraction; (b) Slow degradable fraction; (c) Rate of degradable fraction; (PD): Potential degradability; (ED): Effective degradability; (SEM) Standard Error of The Mean;a-b means with different superscript in the same column were significantly different ($P < 0.05$)

DISCUSSION

The appearance of molds on the surface of the Treated Groundnut Hulls (TGH) was not observed. A strong ammonia smell suggested a higher ammonia concentration in TGH which may have prevented the growth of the mold by acting as a fungicide which agrees with findings by Fadel Elseed *et al.* (2003).

All treatments in the present study significantly ($p<0.05$) increased CP contents in GH compared with untreated one. The increase in CP content 10.7 and 10.9% for 4 and 6% urea treatment levels in this study respectively were similar with the finding Sirohi and Rai (1999), 10.27% for wheat straw treated with 5% urea. The increase in CP content in urea-treated straw over control has also been reported earlier (Jayasuriya and Perrera, 1982; Jai Kishan *et al*., 1986; Dass *et al*., 2000) This increase partially may be due to enhanced its nitrogen content which contributed by the addition of nitrogenous substrate as reported by (NgyUen *et al*., 2001). CP content of TGH was increased significantly with increasing urea level (from 2 to 4 and 6%) may be attributed to their increased solubilization due to higher NH_3 retention (Sarwar *et al*., 2005).

The DM for 4 and 6% urea level treatments was highly degradable, than that of 2% urea level treatment but the proportion of readily degradable fraction increased for all the treatments. An increased degradable fraction of DM may be contributed by an increase in the slowly degradable fraction of DM. Mason *et al*. (1990) suggested that, the increase in the cell walls degradability after ammoniation could have resulted from the effect of the treatment on lignin itself or its linkage. An increased degradable fraction of DM, therefore, may have been attributed to an increased degradability of structural carbohydrates such as hemicelluloses and cellulose for 6 and 4 than 2% urea level treatment. The slowly degradable constant 'b' for the DM obtained in this study for 2 , 4 and 6% urea level lower than 646, 736 and 821 g/kg, respectively, being reported by Rodrigues *et al*. (2009). This difference could be attributed to the difference in diets type of this study (groundnut hulls) and the studies by Rodrigues *et al*. (2009) (grass). Differences in the diets of the fistulated animals can also cause variations in degradability estimates (Mehrez and Ørskov 1977; Kitessa *et al*., 1999; Foster *et al*., 2007; Mohamed and Chaudhry 2008; Rodrigues *et al*., 2009). Moreover, different methods that were used for the washing of bags following rumen incubation can also cause variations in degradation estimates. Rodrigues *et al*. (2009) used cold water in a washing machine for 40 min compared with the washing of bags for the same length of time but under tap water in this study which could have contributed to the variations in these estimates.

The soluble fraction (a) and rate of degradation (fraction c) showed no significant difference among all treatments of NDF degradability. This may be caused by treatment of groundnut hulls with nitrogenous substance such as urea, thereby enhanced the partial solubility of hemicellulose as described by Buettner *et al*. (1982) and Chaudhry (1998). An increased potential degradability fraction of NDF with 6 and 4% level of urea treatments compared with 2% was explainable because, increase urea level resulted in an increase of the efficiency of microbial N supply (Orden *et al*., 2000).

Degradability of NDF fraction was increased significantly for 6 and 4% urea level treatments compared to 2%. Result was similar with those obtained by Attaelmnan *et al*. (2009). They suggested that, the effects of urea on bagasse show that neutral detergent fibre decreases through a decrease in lignin and cellulose. This effect may be due to alkali treatment to cell wall of fibrous materials are modified the bonds between lignin and structural carbohydrate are partially cleared, making it easier for rumen cellulolytic bacteria to colonize and degrade ingested fibrous materials (NgyUen *et al*., 2001). This is also may be due to the fact that, more readily available fibrous are liberated and consequently rumen microbes can multiply faster and this degrades fibrous materials faster (Silva and Ørskov, 1988). However, no significant differences were observed between 4 and 6% level of urea treatments regardless the time of treatments which may have resulted from high amount of nitrogen supply Fadel Elseed *et al*. (2003). The higher degradability values of OM for 4 and 6% level of urea treatments than the 2% could be due to the more suitable structure and solubility of DM and NDF in these feeds which could be easily captured by the rumen microorganisms (Mahadevan *et al*., 1980; Emanuele and Staples 1988; Kong *et al*., 2010). Although, ammoniation improves forage degradability due to hydrolytic action on linkages between lignin and structural polysaccharides, thus increasing OM potentially available for utilization by ruminal microorganisms. Ammonia treatment also changes physical characteristics of forages making them more pliable and increasing hydration which is proportional to digestion rate (Weiss and Underwood, 1995).

REFERENCES

AOAC, 1995. Official Methods of Analysis, 16th ed. Association of Official Analytical Chemists, Arlington, VA, USA, pp: 4, 1-4, 17.

Attaelmnan, B.A., A.M. Fadel Elseed and A.M. Salih, 2009. effect of Albizia lebback or wheat bran supplement on intake, digestibility and rumen fermentation of ammoniated baggasse. J. Applied Sci. Res., 5: 1002-1006.

Buettner, M.R., V.L. Lechtenberg, K.S. Hendrixand and J.M. Hertel, 1982. composition and digestion of ammoniated tall fescue (Festuca arundiancea Schreb) hay. J. Aim. Sci., 54: 273-178.

Chaudhry, A.S., 1998. Nutrient digestion and rumen fermentation in sheep of wheat straw treated with calcium oxide, sodium hydroxide and alkaline hydrogen peroxide. Anim. Feed Sci. Technol., 74: 315-328.

Dass, R.S., U.R. Mehra and A.K. Verma, 2000. Nitrogen fixation and in situ dry matter and fiber constituents disappearance of wheat straw treated wit urea and boric acid in Murrah buffaloes. Asian-Aust. J. Anim. Sci., 8: 1133-1136.

Emanuele, S.M. and C.R. Staples, 1988. Effect of forage particle size on in situ digestion kinetics. J. Dairy Sci., 71: 1947-1954.

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-Aust. J. Anim. Sci., 16: 368-373.

Foster, J.L., J.P. Muir, B.D. Lambert and D. Pawelek, 2007. In situ and in vitro degradation of native Texas warm-season legumes and alfalfa in goats and steers fed a sorghum-Sudan basal diet. Anim. Feed Sci. Technol., 133: 228-239.

Goering, H.K. and P.G. Van Soest, 1970. Fibre analysis (apparatus, reagents, procedures and some applications) Agric Handbook, 379, ARS USDA Washington DC., pp: 1-20.

Jai Kishan, R.S. Dass and U.B. Singh, 1986. Ammoniation of paddy straw and its in sacco dry matter digestibility. Ind. J. Anim. Nutr., 4: 278-281.

Jayasuriya, M.C.N. and H.G.D. Perrera, 1982. Urea-ammonia treatmen of rice straw to improve its nutritive value for ruminants. Agric. Waste., 4: 143.

Kitessa, S., P.C. Flinn and G.G. Irish, 1999. Comparison of methods used to predict the in vivo digestibility of feeds in ruminants. Aust. J. Agric. Res., 50: 825-841.

Kong, Y., R. Teather and R. Forster, 2010. Composition, spatial distribution and diversity of the bacterial communities in the rumen of cows fed different forages. FEMS Microbiol. Ecol., 74: 612-622.

Mahadevan, S., J.D. Erfle and F.D. Sauer, 1980. Degradation of soluble and insoluble proteins by Bacteroides amylophilus protease and by rumen microorganisms. J. Anim. Sci., 50: 723-728.

Mason, V.C., J.E. Cook, M.S. Dhanoa, A.S. Keene, C.J. Hoadley and R.D. Hartley, 1990. Chemical composition, digestibility in vitro and bio degradability of grass hay oven-treated with different amounts of ammonia. Anim. Feed Sci. Technol., 29: 237-249.

Mehrez, A.Z. and E.R. Ørskov, 1977. A study of the artificial fiber bag technique for determining the digestibility of feeds in the rumen. J. Agric. Sci., 88: 645-650.

Ministry of Animal Resources, 2008. General Administration for Planning and Animal Resources Economics, Khartoum, Sudan.

Mohamed, R.A.I. and A.S. Chaudhry, 2008. Methods to study degradation of ruminant feeds. Nutr. Res. Rev., 21: 68-81.

Ngyuen, X.T., C.X. Dan, L.V. Ly and F. Sandsle, 2001. effects of urea concentration, moisture content and duration of treatment on chemical composition of alkali treated rice straw. Livest. Res. Rural Dev., 10.

Orden, E.A., K. Yamaki, T. Ichinohe and T. Fujihara, 2000. Feeding value of ammoniated rice straw supplemented with rice bran in sheep: II. In situ rumen degradation of untreated and treated rice straw. Asian-Aust. J. Anim. Sci., 13: 906-912.

Ørskov, E.R. and I. McDonald, 1979. The estimation of protein degradation in rumen from incubation measurements according to the rate of passage. J. Agric. Sci. (Camb.), 92: 499.

Ørskov, E.R., F. Hovell and F. Mould, 1980. Uso de la técnica de la bolsa de nylon para la evaluación de los alimentos (Use of the nylon bag to evaluate feeds). Prod. Anim. Trop., 5: 213-233.

Preston, T.R. and R.A. Leng, 1987. Matching Ruminant Production Systems with Available Resources in the Tropics and Subtropics. Penambul Book, Armidal, NSW, Australia.

Rodrigues, M.A.M., J.W. Cone, L.M.M. Ferreira, M.C. Block and C.V.M. Guedes, 2009. Relationship between in situ degradation kinetics and in vitro gas production using different mathematical models. Anim. Feed Sci. Technol., 151: 86-96.

Sarwar, M., M.A. Khan and M. Nisa, 2005. Chemical composition and feeding value of urea-treated corncobs ensiled with additives for sheep. Aust. J. Agric. Res., 56: 685-690.

Silva, A.T. and E.R. Orskov, 1988. The effect of five different supplements on the degradation of straw in sheep given untreated barley straw. Anim. Feed Sci. Technol., 19: 289-298.

Sirohi, S.K. and S.N. Rai, 1999. Synergistic effect of urea and lime treatment of wheat straw on chemical composition, in sacco and in vitro digestibility. Asian-Aust. J. Anim. Sci., 7: 1049-1053.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics: A Biometrical Approach, 2nd. Edn. McGraw-Hill, New York, NY, pp: 633.

Sundstøl, F. and E. Owen, 1984. Straw and Others Fibrous By-Products as feed. Elsevier Science Publishers, Amsterdam, pp: 604.

Weiss, B. and J. Underwood, 1995. Improving lower quality dry forages by ammoniation. In: The Ohio State University Extension Agronomy Facts publication # AGF-015-95. Department of Horticulture and Crop Science, The Ohio State University, Columbus, OH, USA.