Influence of Urea Treatment and Soybean Meal (Urease) Addition on the Utilization of Wheat Straw by Sheep

M. S. Kraidees*

Department of Animal Production, College of Agriculture, King Saud University, P. O. Box 2460
Riyadh 11451 Saudi Arabia

ABSTRACT : The effect of ammoniation with urea and with soybean meal (SBM) as a source of urease on the nutritive value of wheat straw was evaluated in sheep. Twenty-four male Najdi lambs were used in a 3×2 factorial design, in which the animals were allocated to three straw treatments: 0% urea-treated (NT), 6% urea-treated (UT) and 2.2% urea-supplemented (US) straws. Each straw treatment was either supplemented or non-supplemented with 70 g SBM kg^{-1} straw during the treatment time with urea, giving a total of six straw treatments. Each of these treatments was individually fed *ad libitum* to 4 lambs, together with 300 g of barley grain/head/day. Total N content of UT and US straws increased significantly ($p<0.001$) as compared to NT straw. The degree of urea hydrolysis, either with or without SBM addition, was nearly similar. Lambs fed either UT or US straw based diets had significantly ($p<0.01$) and numerically ($p>0.05$) higher straw DM intake (g d^{-1} kg^{-1} $BW^{0.75}$), compared to those fed NT straw based diet. Apparent DM or OM digestibilities increased significantly ($p = 0.014$) in lambs fed UT diet, and numerically ($p>0.05$) in lambs fed US diet as compared to those fed NT diet. Fiber (CF, NDF, ADF, cellulose and hemicellulose) digestibility increased to a similar magnitude, averaging 20.2 ($p<0.001$) and 7.8% ($p<0.07$); this corresponds to 35 ($p<0.001$) and 51% ($p<0.001$) in N digestibility and approximately 78 ($p<0.017$) and 105% ($p<0.002$) in N retention, for UT and US diets, respectively, as compared to NT diet. However, the UT diet had higher ($p<0.01$) fiber digestibility over the US diet. Addition of SBM tended to improve ($p = 0.09$) straw DM and digestible OM intakes, while significantly increasing ($p<0.001$) total and digestible CP intakes across all diets. Lambs fed on US diet had higher ruminal ammonia N than those fed on UT ($p<0.05$) or NT ($p<0.001$) diets. However, ruminal pH and molar proportion of the volatile fatty acids did not differ ($p>0.05$) among the treatment diets. This study suggests that US and UT treatments, particularly the latter, improved straw intake, digestibility and N utilization by lambs compared to NT treatment. On the other hand, addition of SBM as a source of urease had a negligible effect on urea hydrolysis. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 7 : 957-965)***

Key Words : Urea, Soybean Meal Urease, Wheat Straw, Digestibility, Lambs

INTRODUCTION

In the kingdom of Saudi Arabia, water represents a major limiting factor for crop and forage production. Therefore; the utilization of agricultural by-product, such as straw is very essential to restore part of the lack of feed and fodder for ruminant feeding. Wheat straw is one of the widely available sources of roughages in Saudi Arabia, with an estimated annual production of 3 million tons (Anon. 2002), and is fed heavily to sheep. However, the use of straw as an animal feed is limited by its low digestibility and inadequate nitrogen (N) content, which in turn has a negative effect on its voluntary intake. Cereal straws contain more than 80% carbohydrate, mainly cell wall polysaccharides. The rumen microorganisms do not utilize much of this cell wall, due to covalent bonding between the polysaccharide and lignin (Hartley and Jones, 1978). It is commonly accepted that chemical treatments of crop residues by alkalis improve their nutritive value, and make them more utilizable by animals. Ammonification of cereal straws by ammonia or urea increased N content and improved palatability, intake and digestibility (Hadjipanayiotou, 1982; Dias-da-Silva and Sundstol, 1986; Tuen et al., 1991; Ahmed et al., 2002; Nair et al., 2002), and no adverse effect on the meat quality and various sensory attributes were observed (Naik et al., 2004). Urea is a safe and cheap compound, with no health risks compared to ammonia. Feeding trials with sheep and goats have shown that animals fed urea treated or supplemented straw ate more and grew faster than animals receiving untreated straw (Djajanegara and Doyle, 1989; Kraiem et al., 1991; Mgheni et al., 1993). Ammoniation through urea depends on plant's content of urease and/or the addition of an exogenous source of this enzyme to release ammonia from urea in an aqueous medium (Jayasuriya and Pearce, 1983; Williams et al., 1984; Dias-da-Silva et al., 1988). Jayasuriya and Pearce (1983) reported that the addition of urease enzyme or any of its sources could reduce the treatment time required to achieve a given level of *in vitro* digestibility. This finding was confirmed by Kraidees (1997) and Khan et al. (1999). Therefore, the objective of the present study was to evaluate the effect of urea treated or urea supplemented wheat straw with or without the addition of soybean meal (SBM) as a source of urease on voluntary intake, nutrients digestibility,

* Corresponding Author: M. S. Kraidees. Tel: +966-1- 4675850, Fax: +966-1-4678474, E-mail: Kraidees@ksu.edu.sa
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Table 1. Chemical composition of the experimental feeds (%, of DM basis)

Item	Straw treatments[a]						RBG[c]
	NT		UT		US		
	SBM addition[b]						
	(–) NTS[1]	(+) NTSB[2]	(–) UTS[3]	(+) UTSB[4]	(–) USS[5]	(+) USSB[6]	
Dry matter (DM)	95.2	95.6	93.7	93.8	80.5	80.8	91.5
Organic matter (OM)	93.1	93.9	93.4	93.1	93.6	93.7	97.8
Crude protein (CP)	4.1	7.2	11.1	13.7	10.8	13.2	11.5
Ether extract (EE)	1.4	1.3	1.2	1.2	1.2	1.1	2.1
Crude fiber (CF)	37.6	35.5	38.7	37.0	36.2	34.0	3.8
Neural detergent fiber (NDF)	80.2	77.4	79.6	77.0	79.8	76.9	25.9
Acid detergent fiber (ADF)	51.8	49.0	52.9	51.0	49.8	47.8	6.2
Cellulose	39.5	38.0	41.0	39.2	38.4	36.5	4.0
Lignin	10.1	9.3	9.8	9.6	9.3	9.4	1.9

[a] NT = Non-treated wheat straw; UT = Urea-treated wheat straw; US = Urea-supplemented wheat straw.
[b] (-) = Without soybean meal addition; (–) = With soybean meal addition. [c] Rolled barley grain.
[1] NTS = Non-treated wheat straw. [2] NTSB = Non-treated wheat straw plus SBM.
[3] UTS = Urea-treated wheat straw. [4] UTSB = Urea plus SBM-treated wheat straw.
[5] USS = Urea-supplemented wheat straw; [6] USSB = Urea plus SBM-supplemented wheat straw.

N utilization, blood and rumen fermentation parameters in Najdi ram lambs.

MATERIALS AND METHODS

Treatment of straws

The experiment was conducted in the Animal Production Department farm of King Saud University, Riyadh, Saudi Arabia. A quantity of air-dry wheat straw (900 kg) was chopped into lengths of approximately 1-3 cm. Straw was divided into six stacks and allocated to three straw treatments of two stacks each: 0% urea-treated [NT], 6% urea-treated [UT] or 2.2% urea-supplemented [US] straws. Each straw treatment was either supplemented or non-supplemented with 70 g SBM kg^{-1} straw at the time of urea treatment, giving the following straw based diets: 1- non-treated wheat straw (NTS), 2- non-treated wheat straw plus SBM (NTSB), 3- urea-treated wheat straw (UTS), 4- urea plus SBM-treated wheat straw (UTSB), 5- urea-supplemented wheat straw (USS) and 6- urea plus SBM-supplemented wheat straw (USSB).

The two stacks of NT straw were left intact, while the UT straw stacks were spread on a concrete floor and sprayed with 1 L of 6% urea solution kg^{-1} air-dry straw. During spraying, each stack was turned and thoroughly mixed, with (UTSB) or without (UTS) SBM addition. Stacks were wrapped tightly in a dark thick polyethylene sheet to eliminate air. After 4 wk storage period, the sheets of the two stacks were opened, and allowed to air-dry for 2 d to diffuse the ammonia onto the atmosphere and aid storage. Next the straw was offered to lambs. The mean ambient temperature during the treatment period of the stacks ranged between a minimum of 14.1-23.8°C and a maximum of 29.1-39.0°C and the relative humidity between a minimum of 7.0-10.6% and a maximum of 12.5-58.4%. The US straw was made two times daily by adding urea to straw either with (USSB) or without (USS) SBM addition, where each pair of straw, UTS and USS or UTSB and USSB was isonitrogenous. The appropriate amount of urea (22 g urea kg^{-1} air-dry straw) was dissolved in 0.2 kg of water, sprayed on the straw, and thoroughly mixed manually before feeding to the lambs.

Animals, diets and design

Twenty-four male Najdi lambs of 39 kg average body weight (BW) were used in a 3×2 factorial arrangement of treatments. Main factors were three straw treatments (NT, UT and US), with or without SBM addition. The lambs were stratified according to their BW and allocated into six equal groups, of four lambs each. Each group was randomly allocated to one of the six straw based diets: NTS, NTSB, UTS, UTSB, USS and USSB, and fed *ad libitum* together with 300 g of rolled barley grain (RBG) and 20 g mineral/vitamin supplement to meet or exceed the maintenance requirements of the lambs. Chemical composition of experimental straws and RBG is shown in Table 1.

Voluntary intake and digestibility determination

Lambs were placed in individual slatted floor pens and the experimental diets were gradually introduced to them for a 10 d changeover period, followed by another 14 d period for rumen adaptation. Voluntary intake of straws was measured over a period of 7 d by offering lambs about 15% more than the amount consumed on the previous day. Diets were offered twice daily at 08:00 and 16:00 h and fresh water was freely available. RBG and mineral/vitamin mixture supplements were given first to ensure complete consumption. Unconsumed straw was removed and weighed daily to estimate the voluntary intake. After

Table 2. Effect of ammoniation with urea and with soybean meal addition on chemical composition and *in vitro* digestibility of the experimental wheat straws (%, of DM basis)

Item	Straw treatments[1]			SE[2]	SBM addition[3]		SE	Significance[4]	
	NT	UT	US		(-)	(+)		T	S
Chemical composition									
OM	93.5	93.3	93.7		93.4	93.6			
CP	5.7[b]	12.4[a]	12.0[a]	0.18	8.7[B]	11.4[A]	0.15	***	***
CF	36.6	37.8	35.1		37.5	35.5			
NDF	78.8	78.3	78.4		79.9	77.1			
ADF	50.4	52.0	48.8		51.5	49.3			
Hemicellulose	28.4	26.3	29.6		28.4	27.8			
Cellulose	38.7	40.1	37.4		39.6	37.9			
IVDMD[5]	44.2[b]	56.1[a]	44.0[b]	0.52	46.6[B]	49.6[A]	0.42	***	***
IVNDFD[6]	36.7[b]	51.9[a]	37.0[b]	0.69	40.9[B]	42.8[A]	0.56	***	*

[1] NT = Non-treated wheat straw; UT = Urea-treated wheat straw; US = Urea-supplemented wheat straw.
[2] Standard error of least square means. [3] (-) = Without soybean meal addition. (+) = With soybean meal addition.
[4] Levels of significance of main effects; effect of the straw treatments [T]; effect of SBM addition [S].
* ($p<0.05$), *** ($p<0.001$). [5] *In vitro* DM disappearance. [6] *In vitro* NDF disappearance.
[a, b, A, B] Within rows, straw treatment or SBM addition means not sharing the same superscript differ significantly at least at ($p<0.05$).

measuring voluntary straw intake, the lambs were moved and housed in metabolic crates. The amount of straw offered for each lamb was equal to the average daily consumed during the voluntary intake period. Straw, RBG and mineral/vitamin supplements were daily weighed, and offered to each lamb at two equal meals for 4 d adjustment period (adapt on the crate) followed by 7 d collection period.

Sampling and analysis

Samples of feed offered and that refused were collected daily pending chemical analysis. Daily feces outputs of each lamb were also collected; weighed, mixed and representative samples (20% aliquots) were taken. Fecal, USS and USSB samples were dried at 55°C for 48 h, to remove their high moisture and stored for later chemical analysis. Urine was collected in a plastic bucket containing 100 ml 4 N HCl solution to prevent ammonia N losses. Daily volume of urine was recorded and a subsample was composited daily and stored at -20°C until analyzed for total N (AOAC, 1990). Composite samples of feeds, orts and feces were ground through a 1mm screen, and analyzed for dry matter (DM) at 105°C overnight and ashed at 600°C to estimate organic matter (OM). Ether extract (EE), crude fiber (CF) and crude protein (CP) contents were analyzed according to AOAC (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and permanganate lignin contents were analyzed according to Goering and Van Soest (1970). Cellulose was taken as the difference between ADF and lignin. Hemicellulose was calculated by subtracting ADF from NDF. Straw samples were analyzed for fiber-bound N (ADF-N) by analysing the ADF residue for total N. Free ammonia N concentration; water-soluble N and unhydrolysed urea were assayed according to AOAC (1990). The *in vitro* DM disappearance (IVDMD) of the straw samples was assessed by the method of Tilley and Terry (1963), as modified by Moore (1970). Digestibility of NDF was determined *in vitro*, where acid pepsin stage was replaced by a NDF determination. The proportion of digested cell wall material to the original cell wall content is a measure of *in vitro* NDF disappearance (IVNDFD).

On the last day of the collection period, ruminal fluid and blood were sampled before and 3 h post the morning feeding. Ruminal fluid samples were collected via a stomach tube using little suction, and strained through four layers of cheesecloth. Rumen pH was immediately measured using a portable pH meter, then 18 ml of strained rumen liquor was acidified with 2 ml 6 N HCl and stored frozen at -20°C for ammonia N and volatile fatty acids (VFA) determination. Frozen ruminal fluids were thawed and centrifuged at 20,000×g for 20 min, and the supernatant was taken for determination of ammonia N concentration. A portion of the supernatant was filtrated through a 0.45-micron vacuum filter apparatus and used for determination of the VFA using a gas liquid chromatography (model 404, Pye Unicam, Philips). Blood samples were collected by jugular venepuncture into acid washed heparinized tubes, centrifuged at 5,000×g for 15 minutes, immediately to obtain plasma. The plasma were decanted and stored at -20°C until analyzed for total protein, albumin and urea N using commercial reagent kits of (Randox laboratories Ltd.). Globulin was estimated as the difference between total protein and albumin.

Statistical analysis

Data for all dependent variables were subjected to analysis of variance using the GLM procedure of SAS (1998) according to the following model:

$$Y_{ijk} = \mu + T_i + S_j + TS_{ij} + E_{ijk}$$

Table 3. Effect of ammoniation with urea on nitrogen (N) fractions of wheat straw

Item	Straw treatments[a]		
	NT	UT	US
Total N content (g kg^{-1} DM)	9.1	19.9	19.2
N retained (% of urea N added[b])	-	37.3	95.8
Water soluble N (g kg^{-1} DM)	2.4	12.3	11.9
% of N retained	-	91.9	93.4
Ammonia N (g kg^{-1} DM)	1.7	6.4	2.4
% of N retained	-	43.6	7.4
ADF bound N (g kg^{-1} DM)	1.8	2.2	1.9
% of N retained	-	3.8	1.0
Residual urea N (g kg^{-1} DM)	-	3.4	10.0

[a] NT = Non-treated wheat straw; UT = Urea-treated wheat straw; US = Urea-supplemented wheat straw.
[b] Assuming 46% nitrogen content of urea as declared by the manufacturer.

Where Y_{ijk} is the K^{th} observation, μ is the common mean, T^{i} is the effect of the I^{th} straw treatments (NT, UT and US), S_j is the effect of the j^{th} SBM addition (with and without), TS_{ij} is the I^{th} straw treatments with the j^{th} SBM addition interactions, and E_{ijk} is the residual error. Since no significant interactions were detected in this study, only main effect means are presented in the tables, thus the straw treatments are pooled over the SBM addition and vice versa. Least squares means were used to compare the differences between treatment means.

RESULTS AND DISCUSSION

Chemical composition and *in vitro* digestibility

Table 2 summarizes the results of chemical composition and *in vitro* DM and NDF disappearance of wheat straw treatments. UT treatment significantly increased CP content of NT wheat straw by 2.2 fold ($p<0.001$); a value closed to that of US treatment 2.1 fold ($p<0.001$). This increase could be attributed to the fixation of N on the straw. Similar values following urea or ammonia treatment were reported by several authors (Kraiem et al., 1991; Mgheni et al., 1993; Ben Salem et al., 1994; Nair et al., 2002; Naik et al., 2004). On the other hand, Dias-da-Silva and Sundstol (1986) and Ahmed et al. (2002) found additional increase in CP content (3.4 and 3.2 fold) when either wheat or rice straws, respectively, were treated with 4% urea. Addition of SBM significantly increased CP content ($p<0.001$) across all treatments. Both UT and US treatments had no significant effect on the fiber constituents of the straw. UT straws showed a small decrease in hemicellulose, with corresponding increases in cellulose, ADF and CF contents compared to NT straws. The changes observed in cell wall structure of UT straws, suggesting that some delignification occurred. These results are consistent with other reports (Dias-da-Silva and Sundstol, 1986; Ben Salem et al., 1994) where wheat straw and sorghum stover, respectively, were treated with either urea or ammonia. Addition of SBM numerically decreased all fiber fractions across all treatment. This could be attributed to alteration of the straw compounds by diluting the concentration of fiber constituents and increasing that of protein content owing to low fiber and high protein content of SBM. The decrease in fiber content of the treated straws with urea and SBM was consistent with others investigators (Kraidees, 1997; Khan et al., 1999; Ahmed et al., 2002). Ahmed et al. (2002) stated that addition of SBM at the time of urea treatment helped to decrease CF content of rice straw by increasing cell wall porosity, which makes polysaccharides more available to enzymatic hydrolysis. Results of *in vitro* disappearance clearly reflected the effect of UT treatment on chemical composition of the straw. The UT treatment led to significant ($p<0.001$) increases in IVDMD and IVNDFD, amounting to approximately 12 and 15% units, respectively, over either US or NT treatments. No significant difference ($p>0.05$) was observed between the US and NT straws. The improvement in digestibility of UT straw suggested that some lignocellulose linkages were broken, allowing more intensive microbial fermentation. Addition of SBM significantly improved IVDMD ($p<0.001$) and IVNDFD ($p<0.05$) across all treatments. This improvement might be due to a decrease of fiber concentration and/or increase in some fermentable energy supply and availability of amino acids; which are known to promote the growth of some ruminal microbes (Maeng et al., 1976). In general, these results are concordant with the findings of other workers (Jayasuriya and Pearce, 1983; Dias-da-Silva et al., 1988; Kraidees, 1997; Khan et al., 1999).

Total N attached and retained due to ammoniation on the straw was 10.8 and 10.1 g kg^{-1} straw DM for UT and US treatments, respectively (Table 3). The N retained as a % of urea N added was 37.3 and 95.8% for UT and US treatments, respectively. Therefore, approximately 63 and 4%, respectively, of the urea N added were lost due to the treatment process. This agrees with the values reported by Ben Salem et al. (1994) when sorghum stover was treated with 5.3% urea and Mgheni et al. (1993) when rice straw was treated with 5% or supplemented with 2% urea. The majority of N present in the UT or US straw was water soluble N (almost 92%, of N retained); this amount was readily available for the rumen microbes. Free ammonia N accounted for 43.6 and 7.4% of N retained for the UT and US straws, respectively. The amounts of bound N to the ADF in the UT and US straw were 3.8 and 1.0% of retained N, respectively. These results agree with those reported by Solaiman et al. (1979) and Ben Salem et al. (1994). Approximately, 11.7 and 94.3% of added urea N remained unhydrolysed in UT and US straws, respectively. On the other hand, the degree of urea hydrolysis in UT treatment after 4 weeks storage, with (UTSB) or without (UTS) SBM addition, was similar (88.0 vs. 88.6% of urea added,

Table 4. Voluntary intake of Najdi lambs fed wheat straw based diets

Item	Straw treatment[1]			SE[2]	SBM addition[3]		Significance[4]		
	NT	UT	US		(–)	(+)	SE	T	S
Straw									
DM intake (g d^{-1})	664.4^{b}	822.7^{a}	752.6^{ab}	50.7	704.8	788.3	41.4		
% of BW	1.62^{b}	2.02^{a}	1.84^{ab}	0.09	1.73	1.92	0.08	*	†
g d^{-1} kg^{-1} $BW^{0.75}$	41.0^{b}	51.0^{a}	46.5^{ab}	2.45	43.6	48.6	2.00	*	†
Total diet									
OM intake (g d^{-1})	889.6^{b}	1035.3^{a}	973.1^{ab}	47.4	926.4	1,005.6	38.7		
CP intake (g d^{-1})	69.5^{b}	134.5^{a}	122.0^{a}	5.73	94.2^{B}	123.1^{A}	4.68	***	***
NDF intake (g d^{-1})	594.2^{b}	714.1^{a}	657.1^{ab}	39.6	633.9	676.4	32.3		
Digestible OM intake (g d^{-1} $kg^{-1}W^{0.75}$)	30.8^{b}	38.6^{a}	35.2^{a}	1.29	33.5	36.2	1.06	**	†
Digestible CP intake (g d^{-1} $kg^{-1}W^{0.75}$)	1.90^{b}	4.90^{a}	4.93^{a}	0.16	3.22^{B}	4.60^{A}	0.13	***	***
Digestible NDF intake, g d^{-1} $kg^{-1}W^{0.75}$	18.2^{c}	26.1^{a}	21.6^{b}	1.18	21.5	22.5	0.97	***	

[1] NT = Non-treated wheat straw based diets; UT = Urea-treated wheat straw based diets;
US = Urea-supplemented wheat straw based diets; [2] Standard error of Least square means.
[3] (-) = Without soybean meal addition; (−) = With soybean meal addition.
[4] Levels of significance of main effects; effect of the straw treatments [T]; effect of SBM addition [S].
† ($p<0.10$), * ($p<0.05$), ** ($p<0.01$), *** ($p<0.001$).
[a, b, c, A, B] Within rows, straw treatment or SBM addition means not sharing the same superscripts differ significantly at least at ($p<0.05$).

respectively). This might be due to the low ureolytic activity of SBM and/or to the longest treatment period (28 d), which made the urea hydrolysis in both treatments similar. Williams et al. (1984) reported that addition of SBM as a source of urease to urea treated barley straw at the time of treatment had no effect on the rate of urea hydrolysis after 10 or 40 d storage period.

Voluntary intake

As expected, lambs fed either UT or US diet had significantly ($p<0.01$) and numerically ($p>0.05$) higher voluntary straw DM intake (g d^{-1} kg^{-1} $BW^{0.75}$), respectively than those fed NT diet, the increases being 24.4 and 13.4% for UT and US straws over NT straw (Table 4). Though lambs fed UT diet had numerically 9.7% higher straw DM intake over those fed US diet. The increase in intake resulting from the ammoniation of the straw could be due to improvement of its palatability and digestibility. The intake from RBG was constant; therefore, the pattern of total DM intake was similar to that observed with straw DM intake. Dias-da-Silva and Sundstol (1986) and Kraiem et al. (1991) reported that wheat straw DM intake in sheep increased significantly by 28 and 31%, respectively, when treated with 4% urea, over untreated straw. Also, Manyuchi et al. (1994) showed an increase in DM intake of maize stover by 24 and 17% when treated with 5% or supplemented at feeding time with 3% urea, respectively, over untreated stover. Compared with NT diet, the total intake (g d^{-1}) of OM and NDF ($p<0.05$) and CP ($p<0.001$) were increased in lambs fed on UT diet. Likewise, lambs fed on US diet had significantly higher ($p<0.001$) the total intake of CP, while increased numerically ($p>0.05$) the total intake of OM and NDF. Several authors attributed such increase in DM intake of ammoniated straw to an increased rate of breakdown of feed particles which in turn increased ruminal rate of passage of indigestible matter and/or to the higher N concentration associated with ammonia or urea treated straw (Oji et al., 1979; Dias-da-Silva and Sundstol, 1986; Djajanegara and Doyle, 1989).

Addition of SBM tended to be improving ($p = 0.09$) straw DM intake (g d^{-1} kg^{-1} $BW^{0.75}$), while significantly raised total diet CP ($p<0.001$) intake (g d^{-1}). Ahmed et al. (2002) stated that calves fed diets based on urea treated rice straw, and containing 4 or 6% levels of SBM at the time of urea treatment had higher ($p<0.05$) DM intake than those fed diets containing no SBM addition. Compared with NT diet, the digestible intake (g d^{-1} kg^{-1} $BW^{0.75}$) of OM, CP and NDF were higher ($p<0.001$) for UT diet. Similarly, the digestible intake of OM and NDF ($p<0.05$) and CP ($p<0.001$) increased with US diet. Dias-da-Silva and Sundstol (1986) reported that both 5% urea and 3% anhydrous ammonia treatments resulted in similar digestible OM intakes, which were higher ($p<0.05$) than those of supplemented (2% urea at feeding time) and unsupplemented wheat straw. Addition of SBM tended to be increasing the digestible OM intake ($p = 0.08$), while significantly increased ($p<0.001$) the digestible intake of CP.

Apparent digestibility of diets

As is shown in Table 5 the apparent digestibility of DM or OM significantly increased by 8.0% ($p = 0.014$) with UT diet in comparison to NT diet. However, with US diet, this increase was only 4.5% with no significant difference ($p>0.05$). These results are consistent with several other reports where sheep were fed diets containing wheat straw supplemented with urea, or treated with urea or ammonia (Dais-da-Silva and Sundstol, 1986, 1989; Kraiem et al., 1991) or either sorghum stover (Ben Salem et al., 1994) or barley straw (Hadjipanayiotou, 1982) treated with urea. On the contrary, neither DM nor OM digestibility was altered

Table 5. Nutrient digestion and nitrogen utilization of wheat straw based diets fed to Najdi lambs

Item	Straw treatment[1]			SE[2]	SBM addition[3]		SE	Significance[4]	
	NT	UT	US		(-)	(+)		T	S
Digestibility coefficients of diets (%)									
DM	53.5^{b}	57.8^{a}	55.9^{ab}	1.09	55.8	55.7	0.89	*	
OM	56.0^{b}	60.2^{a}	58.5^{ab}	1.04	58.2	58.2	0.85	*	
CF	48.8^{b}	58.6^{a}	52.3^{b}	1.27	53.8	52.6	1.04	***	
NDF	49.3^{c}	59.1^{a}	53.2^{b}	1.21	54.3	53.4	0.99	***	
ADF	43.7^{b}	52.3^{a}	47.4^{b}	1.39	48.4	47.1	1.13	**	
Hemicellulose	57.5^{c}	70.2^{a}	61.4^{b}	1.16	63.2	62.8	0.95	***	
Cellulose	52.2^{c}	62.1^{a}	56.7^{b}	1.20	57.5	56.5	0.98	***	
Digestible OM	53.1^{b}	56.8^{a}	55.5^{ab}	0.99	55.1	55.2	0.81	*	
Digestible CP	3.24^{c}	7.13^{b}	7.76^{a}	0.13	5.22^{B}	6.88^{A}	0.11	***	***
Digestible NDF	31.1^{c}	38.0^{a}	33.9^{b}	0.94	35.0	33.6	0.77	***	
TDN[5]	54.0^{b}	57.7^{a}	56.3^{ab}	0.95	55.9	56.0	0.77	*	
Nitrogen balance:									
N intake, (g d^{-1})	11.1^{b}	20.4^{a}	19.2^{a}	0.95	14.9^{B}	18.9^{A}	0.77	***	**
Fecal N loss (g d^{-1})	6.19^{b}	8.44^{a}	6.65^{b}	0.45	6.70	7.48	0.37	**	
N digestibility (%)	43.2^{c}	58.5^{b}	65.3^{a}	1.24	52.5^{B}	58.8^{A}	1.01	***	***
Urinary N loss (g d^{-1})	1.80^{b}	6.50^{a}	6.27^{a}	0.39	3.86^{B}	5.85^{A}	0.32	***	***
N retention, g d^{-1}	3.08^{b}	5.47^{a}	6.31^{a}	0.64	4.36	5.55	0.52	**	
N retention (%)	27.3	26.7	32.6	2.78	28.8	29.0	2.27		

[1] NT = Non-treated wheat straw based diets; UT = Urea-treated wheat straw based diets;
US = Urea-supplemented wheat straw based diets; [2] Standard error of least square means.
[3] (-) = Without soybean meal addition; (-) = With soybean meal addition.
[4] Levels of significance of main effects; effect of the straw treatments [T]; effect of SBM addition [S].
[5] Total digestible nutrients. * ($p<0.05$), ** ($p<0.01$), *** ($p<0.001$).
[a, b, c, A, B] Within rows, straw treatment or SBM addition means not sharing the same superscript differ significantly at least at ($p<0.05$).

by diets containing ammoniated wheat straw (Herrera Saldana et al., 1982) or urea treated maize stover (Manyuchi et al., 1994). In the present study, both urea treatments (UT or US diet) increased fiber (CF, NDF, ADF, cellulose and hemicellulose) digestibilities when compared with NT diet. In US diet the degree of these increases was almost similar for all fiber components averaging 7.8% (3.9 digestibility units; $p<0.07$), while in UT diet the effect was even more pronounced, averaging 20.2% (10.1 units; $p<0.001$). However, the UT diet had higher ($p<0.01$) fiber digestibility over the US diet. This could be attributed to several factors: 1- the sustained release of ammonia from urea hydrolysis, which acts mainly on the linkages among cell wall components such as those between lignin and cellulose or hemicellulose, making the fiber more available for microbes, 2- the increased supply of rumen degradable N; 3- the presence of barley grain as a fermentable energy supplement, which, in turn, improves the fermentation in the rumen.

The significance of UT over US straw treatment has been confirmed by other investigators (Tuen et al., 1991; Mgheni et al., 1993). The presently observed increase in fiber digestibilities as a result of urea treatment or supplementation is concordant with other reports where ammoniated cereal straw was given as a sole feed or as a major portion of the diet (Hadjipanayiotou, 1982; Dias-da-Silva and Sundstol, 1986; Djajanegara and Doyle, 1989; Ben Salem et al., 1994). Conversely, Zorrilla-Rios et al. (1989) indicated that ammoniation had no significant effect on NDF digestibility. Better digestibility of urea treated or supplemented wheat straw based diets were reflected on improvement of the nutritive value of the diets in terms of digestible nutrients (Table 5). Either UT or US diet increased digestible OM ($p = 0.016$; $p = 0.11$, respectively), CP ($p<0.001$), NDF ($p<0.001$; $p<0.05$, respectively) and TDN ($p = 0.012$; $p = 0.095$, respectively) compared to NT diet. However, with the exception of digestible OM and TDN ($p>0.05$), the difference between the former two treatments was significant ($p<0.01$) only for digestible CP and NDF. Addition of SBM did not significantly ($p>0.05$) affect apparent digestibility of all nutrients and all digestible nutrients, except that of digestible and apparent digestibility of CP, which increased significantly ($p<0.001$) across all diets. Ahmed et al. (2002) stated that the addition of 6% SBM to urea treated (4%) rice straw at the time of treatment increased digestible CP and TDN of the diets, while no effect on digestible OM and CF was observed in comparison to SBM -free urea treated straw.

Nitrogen utilization

Lambs fed UT and US straw based diets had similar levels of N intake, which were higher ($p<0.001$) than those recorded in lambs fed NT straw based diet (Table 5). Compared to NT diet, both UT and US diets significantly ($p<0.001$) increased N digestibility by 35 and 51%, respectively, indicating that some of the N bound to the

Table 6. Rumen fermentation and blood parameters of Najdi lambs fed wheat straw based diets

Item	Straw treatment[1]			SE[2]	SBM addition[3]		SE	Significance[4]	
	NT	UT	US		(–)	(+)		T	S
Ph	7.14	7.24	7.19	0.07	7.23	7.15	0.06		
Ammonia N, mg dl-1	15.0^b	19.8^b	28.3^a	2.51	18.6	23.5	2.27	**	
Total VFA, mM l-1	48.2	51.6	47.5	2.64	48.8	49.4	2.16		
Molar proportions of VFA (mol/100 mol)									
Acetate	73.1	73.3	72.9	0.54	72.8	73.4	0.44		
Propionate	17.8	17.1	17.1	0.59	17.9	16.8	0.47		
Isobutyrate	0.76	0.69	0.88	0.08	0.74	0.82	0.07		
Butyrate	6.98	7.53	7.47	0.33	7.20	7.46	0.27		
Iso-valerate	0.84	0.89	0.99	0.11	0.85	0.96	0.09		
Valerate	0.55^b	0.53^b	0.64^a	0.03	0.54	0.61	0.03	*	†
Blood plasma parameters									
Total protein (g dl^{-1})	7.52^{ab}	7.01^b	7.89^a	0.23	7.34	7.61	0.20	*	
Albumin (g dl^{-1})	2.96	2.98	3.14	0.10	2.97	3.08	0.08		
Globulin (g dl^{-1})	4.56	4.03	4.75	0.26	4.37	4.53	0.22		
Albumin:globulin	0.71	0.76	0.72	0.06	0.73	0.73	0.05		
Urea N (mg dl^{-1})	8.4^b	16.9^a	18.7^a	1.15	14.1	15.3	1.32	***	

[1] NT = Non-treated wheat straw based diets; UT = Urea-treated wheat straw based diets.
US = Urea-supplemented wheat straw based diets; [2] Standard error of Least square means.
[3] (-) = Without soybean meal addition; (–) = With soybean meal addition.
[4] Levels of significance of main effects: effect of the straw treatments [T]; effect of SBM addition [S].
† (p<0.10), * (p<0.05), ** (p<0.01), *** (p<0.001).
[a, b] Within rows, straw treatment means not sharing the same superscript differ significantly at least at (p<0.05).

straw was available to rumen microbes. The lower N digestibility of NT diet was associated with higher fecal N output as percentage of N intake (55.8%), suggesting poorer digestion and utilization of N, than in the UT and US diets (41.4 and 34.6%), respectively. Similar results were reported by several investigators (Dias-da-Silva and Sundstol, 1986; Kraiem et al., 1991; Ben Salem et al., 1994). Lowering N digestibility in lambs on UT diet to levels lower than those on US diet might be ascribed to tightly bound N in the straw by urea treatment. It might also be caused by enhancement of protein synthesis by ruminal and intestinal microflora, increased secretion of endogenous matter into the intestinal tract, or poorer digestion and absorption of microbial and endogenous matter (Dias-da-Silva and Sundstol, 1986). Expectedly, the UT and US diets increased N retention (g d^{-1}) by averages of 77.6% (p = 0.017) and 104.9% (p = 0.002), respectively, compared with NT diet. This could be attributed to the treatment and the high N intake by lambs. This result is consistent with other studies (Djajanegara and Doyle, 1989; Kraiem et al., 1991; Ben Salem et al., 1994; Manyuchi et al., 1994). In spite of the low N intake in lambs fed NT diet, the N retention was relatively high. This could be due to an extremely low urinary N loss in these lambs. Addition of SBM significantly increased N digestibility (p<0.001) and N retention (with no significant difference; p = 0.13) across all diets.

Rumen fermentation and blood plasma parameters

Straw treatments significantly (p<0.01) affected the ruminal ammonia N concentration, while little variation of ruminal pH values was observed (Table 6). Hadjipanayiotou (1982) and Mgheni et al. (1994) reported that feeding urea treated straw did not significantly alter ruminal pH. Mould et al. (1983) stated that the rate of degradation of straw is optimal when ruminal pH is maintained at 6.7±0.15; with a pH of less than 6.1, cellulolysis is inhibited. The average pH value of 7.2 obtained in this study suggests that all the diets used provide good condition for cellulolysis. Lambs fed the US diet had higher ruminal ammonia N over those fed UT and NT diets by 42.9% (p<0.05) and 88.7% (p<0.001), respectively. This increase is apparently due to the increase of degradable urea, thus agrees with the results of Herrera Saldana et al. (1982) and Streeter and Horn (1984). The higher rumen ammonia N concentration with US treatment as compared to UT treatment is consistent with the results obtained by Djajanegara and Doyle (1989). Zorrilla-Rios et al. (1989) and Mgheni et al. (1994) who reported that ammoniation of straw yielded lower (p<0.01) rumen ammonia N concentration than urea supplementation straw. Satter and Slyter (1974) suggested that a concentration of 5 mg ammonia N dl^{-1} of rumen fluid was sufficient to support maximum microbial growth. These authors also noted that levels up to 80 mg of ammonia dl^{-1} did not inhibit microbial growth. Accordingly, the degree of ammonia N concentrations in the present study was expected to provide better fermentation conditions to maximize the microbial growth and ruminal digestion with all diets, especially UT based diet. The addition of SBM had no significant effect on either pH or ammonia N concentration.

Except valerate ($p<0.05$), ruminal total VFA concentrations and the molar proportion of the individual fatty acids were not markedly affected by ammoniation. In all diets, rumen acetate formed the highest proportion, followed by propionate and butyrate. This trend indicated that the diets had a similar fermentation pattern in the rumen, which agrees with the results of Herrera Saldana et al. (1982) and Mgheni et al. (1994) who reported that total VFA concentration did not differ among treatments ($p>0.05$), and that no differences existed in molar proportion of the individual fatty acids among the untreated and ammoniated straw diets. Rumen fermentation parameters did not vary significantly with the addition of SBM, however valerate tended to be lower ($p = 0.08$) with SBM addition. Neither UT nor US straw treatments significantly affected plasma total protein (TP) concentration compared to the NT straw treatment (Table 6). Lambs fed Both UT and US diets had higher ($p<0.001$) plasma urea N than those fed NT diet. However, there was no significant difference ($p>0.05$) between the UT and US treatments. The increase in plasma urea N due to ammoniation agrees with the findings reported by Herrera Saldana et al. (1982) and Streeter and Horn (1984). No effect was observed in plasma urea N between sheep fed ammoniated wheat straw and those fed untreated straw (Males and Gaskins, 1982). Addition of SBM had no significant ($p>0.05$) effect on any of the plasma parameters investigated.

CONCLUSIONS

The present data confirm that both treatment and supplementation of wheat straw with urea increased straw intake, N content, and improved nutrient digestion and N utilization by lambs. Most of these improvements were enhanced by SBM addition as a source of protein and energy, but no effect was evident for SBM as a source of urease. Urea treatment is more effective than urea supplementation in improving the nutritive value of wheat straw for lambs.

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