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Effect of wheat straw urea treatment and *Leucaena leucocephala* foliage hay supplementation on intake, digestibility, nitrogen balance and growth of lambs

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This study evaluated the effect of wheat straw urea treatment and *Leucaena leucocephala* (LL) foliage hay supplementation on intake, digestibility, nitrogen balance and growth of Ethiopian highland sheep. Thirty-six yearling male lambs were randomly allotted, in randomized complete design, to six dietary treatments:- untreated wheat straw (T1); urea treated wheat straw (T2); T2 plus 100, 200, 300 g LL in T3, T4, T5 respectively, and T1 plus 300 g LL per lamb/day (T6). The lambs were fed for three months. Urea treatment increased straw crude protein (CP) content (g kg^{-1}DM) (32 vs. 60) and decreased neutral detergent fiber (NDF) (807 vs. 743), acid detergent fiber (ADF) (523 vs. 504) and acid detergent lignin (ADL) (75 vs. 70). Straw intake was increased (P<0.001) with urea treatment and supplementation. Total DM intake (g/day) peaked (P<0.001) in T5 (750) compared to T6 (546.9). Lambs in T2 gained 10.7, while lambs in T1 lost 33.9 g/day. The highest average daily gain (47.2 g) was achieved in T5. Digestibility of DM, organic matter (OM) and CP was higher (P<0.001) in T2 than T1. Supplementation increased the digestibility of DM, CP and Ash significantly. Digestibility of nutrients, except CP, was higher (P<0.001) in T5 than T6. Nitrogen balances (g/day) were positive, except in T1 (-0.71 g/day) and increased (P<0.001) with supplementation. Total nitrogen excretion (g/day) was higher (P<0.001) in T2 (4.64) than T1 (2.97) and increased with supplementation. It is concluded that combined use of urea treatment and LL supplementation improves feed utilization and lambs' performance better than using them separately.

Key words: Wheat straw, urea treatment, *leucaena*, intake, live weight, lambs.

INTRODUCTION

Inadequate nutrition is one of the production constraints affecting livestock productivity in Ethiopia. Under traditional system of production, ruminant animals mainly relay on mature grasses and crop residues (Seyoum and Zinash, 1989), which are inherently high in fiber and low in available protein and energy (Ash, 1990; Preston, 1995). The deficit in nutrient availability peaks during dry season when both the quality and quantity of available feeds deteriorate at large. Moreover, increased human population at highlands has resulted in expansion of cropping, at the

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expense of grazing lands that in turn increases availability of crop residues as major feed resource for ruminants. Wheat straw, which is the major crop residue and feed resource base for livestock in wheat based framings of Ethiopian highlands (Seyoum and Zinash, 1989; Keftassa, 1988), is equally devoid of essential nutrients such as protein, energy and minerals. It is likely that under protein and energy deficient diet, feed intake and digestibility fall below requirement for maintenance. Several strategies have been employed to improve the nutritive values of crop residues. Conventional concentrates such as oilseed cakes and grains are rich in nutrients and used to balance the nutritional deficits of poor quality roughages. However, their use by resource limited farmers is unlikely possible due to its high cost and low availability.

On-farm production of improved forages such as grasses and herbaceous legumes at cropping areas is often impractical by most of the farmers due to increased input costs, scarcity of land and higher degree of management it requires. On the other hand, the potential for increasing digestibility and intake of locally available crop residues through treating with alkali has been widely researched and reviewed (Ibrahim and Schiere, 1989; Sundstøl and Coxworth, 1984). In this regard, urea treatment has most practical significance in the tropics acting as an alkali and source of nitrogen, and is effective in improving nutritive values of roughages. Treating poor quality roughages using chemicals such as urea may support animal performance little above maintenance requirement; hence, it requires additional supplements (Orden et al., 2000). Supplementations with protein-rich foliages of fodder trees have been shown to increase the efficiency of poor quality roughage utilization in ruminants. The production of selected multipurpose trees such as *leucaena* and sesbania that establish easily and require less agronomic inputs (Mengistu, 1997) is practical at smallholder farmers, and are rich source of readily fermentable nitrogen and energy (Kaitho et al., 1998; Melaku, 2002). *Leucaena leucocephala* is among important protein sources used to augment ruminants on poor quality roughages (Norton, 1994; Nigussie et al., 2000; Aregheore and Perera, 2004).

The aim of this study was to examine the combined effect of wheat straw urea treatment and LL foliage hay supplementation on nutrient intake, digestibility, nitrogen balance and growth of lambs.

MATERIALS AND METHODS

Study area

The experiment was conducted at Debre Zeit Agricultural Research Center, Ethiopia, located at 45 km south east of Addis Ababa, and between 8.44° N latitude and 39.02° E longitude. The altitude is about 1900 m above sea level. The average annual rainfall is 845 mm and the annual minimum and maximum temperatures are 10 and 22°C, respectively.

Feed preparation

Wheat straw (*Triticum durum*) grown on black soil of Debre Zeit Agricultural Research farm was collected right after grain harvest, chopped to about 5 cm length, urea treated or untreated and used as basal diet. Two adjacent pits each with length-2 m, width-2 m and height-2 m were prepared side by side and used alternately for straw urea treatment. The straw was treated with urea solution prepared at a rate of 40 g of urea dissolved in 0.8 L water per kg straw used. The walls and substratum of the pit was covered with polyethylene sheet. Urea solution was uniformly sprayed on the straw followed by mixing it manually and placing in a pit. The straw was trampled and well compressed using group of men, and the same procedure was repeated until it filled to the pit capacity. The pit was then made an air tight sealing with the plastic sheet and loading a mass of soil (30 cm thick) on top and left unopened for 21 days, during which the ambient temperature ranged between 13.5 and 24.4°C. At the end of ensiling period, only straw amounted to daily offer was taken and ventilated overnight to remove residual ammonia before offered to lambs.

Moreover, ample amount of foliage from LL trees (accession: Cunninghum 8) grown near the research station was collected and air dried.

Animals and treatments

Thirty-six yearling intact male Arsi-Bale lambs with average initial body weight 15.6±0.98 kg were purchased from local market, vaccinated for sheep pox and anthrax and treated against internal parasites. Before commencing the experiment, the animals were adapted to experimental diets for 14 days and randomly allocated to one of the six treatments (six animals per treatment) in complete randomized design. Dietary treatments were: untreated wheat straw (T_1), urea treated wheat straw (T_2), T_2 + 100 g LL (T_3), T_2 + 200 g LL (T_4), T_2 + 300 g LL (T_5) and T_1 + 300 g LL (T_6). The lambs were managed in individual pen with concrete floor.

Intake and growth

Intake and growth trial was conducted for three months. Wheat straw was weighed and offered ad libitium to the experimental animals ensuring a daily refusal of 20% based on previous days intake, while *leucaena* foliage hay was supplemented to each animal once daily between 08:00 and 09:00 h. Water and mineral licks were freely available to all animals. Wheat straw refusal was collected and weighed each morning for each animal, followed by taking representative samples that was bulked and sub-sampled every two weeks. Samples of urea treated straw were placed in deep freezer (at -20°C) to prevent ammonia loss pending chemical analysis. Live weight of each animal was taken every fourteen days after an overnight fasting.

Digestibility and nitrogen balance

At the end of intake and growth trial, three lambs were randomly selected per treatment and transferred to metabolic crates with slotted floor. Lambs had adaptation period of three days to cage feeding, attached urinary funnels and fecal bags. As for growth and intake trial, data on feed offered and refusal were taken daily. Feces and urine were collected for seven days. Urine was collected over 24 h using urinary funnel piped to the collection bottles containing 2 ml 10% sulphuric acid for preservation purpose. Collection of feces was done using plastic bags tied to each animal. Ten percent of the daily collected feces and urine per lamb was sampled and stored in deep freeze at -20°C until used for chemical

Table 1. Chemical compositions of wheat straw and *L. leucocephala* foliage hay.

Variable	Wheat straw		*Leucaena*
	Untreated	Urea treated	
DM (g Kg^{-1}, as fed)	887	699	861
Composition (g Kg^{1}DM)			
Ash	91	96	107
OM	909	904	893
CP	32	60	276
P	1	1	2
Ca	2	2	24
NDF	807	743	425
ADF	523	504	309
ADL	75	70	93
ADF ash	37	40	nd
Hemicellulose	284	239	116
Cellulose	448	433	215
GE(Mj/kgDM)	17.6	18	20.9

nd = not determined.

analysis.

Chemical analysis of samples

Feed samples were ground to 1 mm size using a Wiley mill. Dry matter, CP (N*6.25), ash, calcium and phosphorus contents were assayed for feed and fecal samples using the methods of AOAC (1990) and NDF, ADF, ADL and ADF ash using the procedures of Van Soest et al. (1991). Hemicellulose and cellulose contents of roughages were determined by finding the difference between NDF and ADF and ADF and ADL, respectively. Gross energy was determined using bomb calorimeter (Harris, 1970).

Statistical analysis

Average daily live weight gain of lambs was determined by regressing live weight gained in two weeks interval over days of feeding. Efficiency of feed utilization (EFU) was determined as a ratio of live weight gain (g) to DM intake (kg). The substitution rate (SR) of straw intake by supplement intake was determined by dividing the difference of straw intake between the control and other dietary treatments for the supplement intake (Ponnampalm et al., 2004); where, T2 was a control diet for T3, T4 and T5; and T1 for T6. Data were statistically analyzed using the general linear model (GLM) procedure of statistical analysis systems (SAS, 1999). When ANOVA declared difference, the treatment sum of squares were partitioned into linear components of non-orthogonal contrasts.

RESULTS

Chemical composition

The chemical composition of untreated and urea treated wheat straw and *leucaena* foliage hay is shown in Table 1. The composition of CP (N × 6.25), minerals and gross energy were higher in *leucaena* than straws. With the exception of ADL content, cell wall fractions were markedly higher in straw than foliage. The relatively higher contents of CP, calcium, phosphorus and gross energy in *leucaena* foliage revealed its paramount nutritional importance to augment ruminants on poor quality's roughages. Urea treatment increased straw CP by 87.5% over untreated straw (32 versus 60 g kg^{-1} DM) and decreased the content of NDF, ADF, ADL, hemicellulose and cellulose by 7.9, 3.6, 6.7, 1.6 and 3.3%, respectively. However, there was a slight increment in Ash, ADF ash and GE contents of straw due to ammoniation.

Nutrient intake

Dry matter intake of straw was higher (P<0.001) in lambs fed on sole urea treated straw (566.7 g/day) than untreated straw alone (323.1 g/day), where intake of CP, ash, GE, Ca, P and fiber fractions were also increased significantly (P<0.001) with straw treatment. Improved intake of urea treated cereal straws in ruminants have been reported in other studies (Dias-da-Silva and Sundstøl, 1986; Oosting et al., 1993). The highest voluntary DM consumption of treated straw (594 g/day) was achieved by supplementing 100 g/day of LL, thereby depressed significantly (P<0.001) with increased supplementation. As the result, the substitution effect of *leucaena* for straw was noticed at a rate of 0.13 in T4 and 0.27 in T5. Similarly, intake of treated straw OM, CP, ash, calcium, phosphorus, fiber fractions and GE were reduced (P<0.001) upon increasing the amount of supplement. However, intake of total DM and associated nutrients, except NDF and ADF, was significantly

Table 2. Mean values of nutrient intake in lambs fed on urea treated/untreated wheat straw and supplemented with LL foliage.

Nutrient		Dietary treatments						SEM	Significance level			
		T1	T2	T3	T4	T5	T6		Treat	T2 vs. T6	T5 vs. T6	T2 vs (T3, T4, T5)
DM	Straw	323.1^{d}	566.7^{ab}	594.6^{a}	544.6^{b}	501.3^{c}	298.2^{d}	12.7	***	***	***	ns
	Total	323.1^{d}	566.7^{c}	680.1^{b}	711.6^{b}	750.9^{a}	546.9^{c}	13.08	***	ns	***	***
OM	Straw	291.9^{d}	511.3^{ab}	536.7^{a}	491.3^{b}	453.4^{c}	271.9^{d}	11.13	***	***	***	ns
	Total	291.9^{d}	511.3^{c}	613.8^{b}	641.9^{b}	678.4^{a}	496.1^{c}	11.85	***	ns	***	***
CP	Straw	11.7^{d}	31.4^{ab}	32.9^{a}	30.2^{b}	27.2^{c}	9.9^{d}	0.64	***	***	****	ns
	Total	11.7^{e}	31.4^{d}	56.5^{c}	76.6^{b}	96.6^{a}	78.7^{b}	0.93	***	***	***	***
Ash	Straw	31.2^{d}	55.4^{ab}	57.8^{a}	53.2^{b}	47.9^{c}	26.3^{e}	1.16	***	***	***	ns
	Total	31.2^{e}	55.4^{c}	66.3^{b}	69.7^{ab}	72.6^{a}	50.8^{d}	1.24	***	*	***	***
Ca	Straw	0.6^{d}	1.4^{ab}	1.5^{a}	1.4^{b}	1.2^{c}	1.2^{c}	0.03	***	***	***	*
	Total	0.6^{f}	1.4^{e}	3.2^{d}	4.7^{c}	6.2^{a}	5.4^{b}	0.07	***	***	***	***
P	Straw	0.32^{c}	0.41^{ab}	0.43^{a}	0.40^{b}	0.35^{c}	0.28^{d}	0.01	***	***	***	ns
	Total	0.32^{e}	0.41^{d}	0.6^{c}	0.7^{b}	0.8^{a}	0.7^{b}	0.01	***	***	***	***
NDF	Straw	250.6^{d}	441.1^{ab}	463.6^{a}	423.4^{b}	3903^{c}	237.2^{d}	9.67	***	***	***	ns
	Total	250.4^{d}	441.1^{b}	441.1^{b}	441.1^{b}	496.6^{a}	343.5^{c}	9.96	***	***	***	***
ADF	Straw	155.4^{d}	309.2^{ab}	324.0^{a}	324.0^{a}	275.1^{c}	275.1^{c}	6.8	***	***	***	ns
	Total	155.4^{d}	309.2^{b}	350.5^{a}	351.4^{a}	352.7^{a}	223.9^{c}	7.0	***	***	***	***
ADL	Straw	15.8^{c}	38.1^{a}	40.5^{a}	38.8^{a}	33.8^{b}	14.6^{c}	0.87	***	***	***	ns
	Total	15.8^{e}	38.1^{d}	48.5^{c}	54.4^{b}	57.2^{a}	38.1^{d}	0.97	***	ns	***	***
[1]ADF ash	Straw	14.3^{c}	22.1^{a}	23.2^{a}	19.6^{b}	19.4^{b}	12.2^{d}	0.48	***	***	***	*
GE	Straw	5.6^{d}	10.2^{ab}	10.6^{a}	9.80^{b}	9.05^{c}	5.12^{d}	0.22	***	***	***	ns
	Total	5.6^{e}	10.2^{d}	$12..4^{c}$	13.2^{b}	14.1^{a}	10.10^{d}	0.23	***	ns	***	***

Means in the same row with different letters are statistically different (P<0.05), SEM = standard error of mean, ns = not significant, * = P<0.05, ** = P< 0.01, *** = P< 0.001, Straw [1]ADF ash = total ADF ash as its composition in LL is negligible.

(P<0.001) increased with increased levels of supplementation. The increased (P<0.001) intake of ADL with increased supplementation could also be associated with its high concentration in *leucaena*. Lambs supplemented with 300 g/day of *leucaena* on urea treated straw showed higher (P<0.001) intake of diet and straw DM, OM, CP, ash, Ca, fiber fractions and GE than the group on untreated straw at similar supplementation. In this regard, changes in straw DM intake by 68% (298 versus 501 g/day) and diet DM intake by 37% (546.9 versus 750.9 g/day) were noticed due to urea treatment effect alone.

On the other hand, total DM intake and the associated nutrients' intake were significantly higher (P<0.001) in lambs on untreated straw with 300 g/day *leucaena* (T6) compared to lambs on untreated straw (Table 2).

Live weight change

Table 3 shows the live weight change of lambs. There was variation (P<0.001) among dietary treatments in daily gain of lambs. Severe live weight loss (-33.9 g/day) was noticed in lambs maintained on sole untreated wheat

Table 3. Live weight change and efficiency of feed utilization in lambs fed on urea treated or untreated wheat straw and supplemented with *L. leucocephala* foliage.

Treatment (N = 6)	Mean initial weight (kg)	Mean final weight (kg)	ADG			EFU (g gain kg^{-1} tDMI)
			g/day	g $kg^{-1}W^{0.75}$	g g^{-1} DMI supplement	
T1	15.5	13.0	-33.9[d]	-4.4[c]	0	-117.1[c]
T2	15.9	16.7	10.7[c]	1.6[b]	0	18.7[b]
T3	15.7	18.1	25.8[b]	3.2[ab]	0.29[a]	41.4[ab]
T4	15.8	20.0	43.5[a]	5.2[a]	0.26[ab]	62.8[a]
T5	15.8	20.4	47.2[a]	5.6[a]	0.18[bc]	67.6[a]
T6	15.9	18.6	29.2[b]	3.6[ab]	0.11[c]	55.9[a]
SEM	-	-	0.48	0.97	0.034	11.6
Significance treatment	-	-	***	***	***	***
T2 vs. (T3, T4, T5)	-	-	***	*	***	**
T2 vs. T6	-	-	***	ns	**	*
T5 vs. T6	-	-	*	ns	ns	ns

Means in the same column with different letters are statistically different (P<0.05), SEM = standard error of mean, ns = not significant, * = P<0.05, ** = P< 0.01, *** = P< 0.001.

straw, while lambs on sole urea treated straw gained 10.7 g/day, showing a considerable importance of urea treatment in improving the nutritive value of wheat straw. The highest average daily gain (47.2 g/day) of lambs was attained by supplementing 300 g/day of *leucaena* on treated straw, but was not significantly different (P>0.05) from lambs supplemented with 200 g/day *leucaena*. Expressed per g DMI of supplement, the highest gains (0.29 and 0.26) on treated straw based feeding were achieved at lower levels (100 and 200 g/day) of supplementations. Lambs fed on urea treated straw with 300 g/day *leucaena* had higher (P<0.001) daily gain compared to lambs on untreated straw at equal amount of supplement. Figure 1 shows trends in live weight change of lambs over feeding period. Unlike the group maintained on sole untreated straw, lambs fed on sole urea treated straw maintained live weight throughout feeding period. Supplementation of *leucaena* to lambs on either urea treated or untreated straw had sown increasing trend of live weight change. Increases in live weight were peaked at about two months of feeding and then remained nearly constant. This implies that extended feeding beyond this period may not be biologically and economically sound using the present diets.

Efficiency of feed utilization (EFU) was significantly different (P<0.001) among dietary treatments. Urea treatment shifted wheat straw utilization efficiency from -117.1 to 18.7g kg^{-1} DMI. Despite the higher gains and higher feed DM intakes at higher levels of *leucaena*, there was no significant difference (p>0.05) in EFU among lambs on treated straw. Lambs supplemented with 300 g/day *leucaena* on urea treated and untreated straw showed higher (P<0.05) EFU (55.9, 67.6) than the group on sole treated straw (18.7 g kg^{-1} DMI). The increase in EFU and live weight change with increased DMI at higher levels of supplementation could be due to increased DM digestibility. The optimal level of *leucaena* as supplement to sheep fed on urea treated straw (g gain kg^{-1} DMI *leucaena*) was 200 g/day, where optimum efficiency of feed utilization was also obtained.

Digestibility

Urea treatment increased the digestibility of straw DM, OM, CP, NDF, ADF and DE by about 16.3, 14.8, 22.5, 20.8, 15.2 and 18.4%, respectively, over untreated straw (Table 4). Digestible energy of straw was increased by about 45% (411 versus 595 g kg^{-1} DM) due to ammoniation. Compared to sole urea treated straw, supplementation of *leucaena* to treated straw considerably increased digestibility of feed DM (P<0.01), CP (P<0.001) and ash (P<0.001), but was not significantly improved (P>0.05) the digestibility of OM, NDF and ADF. Supplementation of 300 g/day to lambs on untreated wheat straw significantly (P<0.001) increased the apparent digestibility coefficients of DM, CP, OM, ash and GE over sole untreated straw. Urea treatment alone generally resulted in higher (P<0.001) digestibility coefficients of DM, OM, CP, NDF and GE than untreated straw supplemented with 300 g *leucaena*. Except for CP, the digestibility coefficients of nutrients were higher (P<0.001) in urea treated than untreated wheat straw fed lambs both at 300 g/day *leucaena*.

Increasing level of supplementation resulted in valuable improvement in the digestibility values of DM, CP and total ash. Lambs kept on sole urea treated straw had shown higher digestibility values of DM, OM, CP, NDF, ADF and DE than lambs on untreated straw with 300

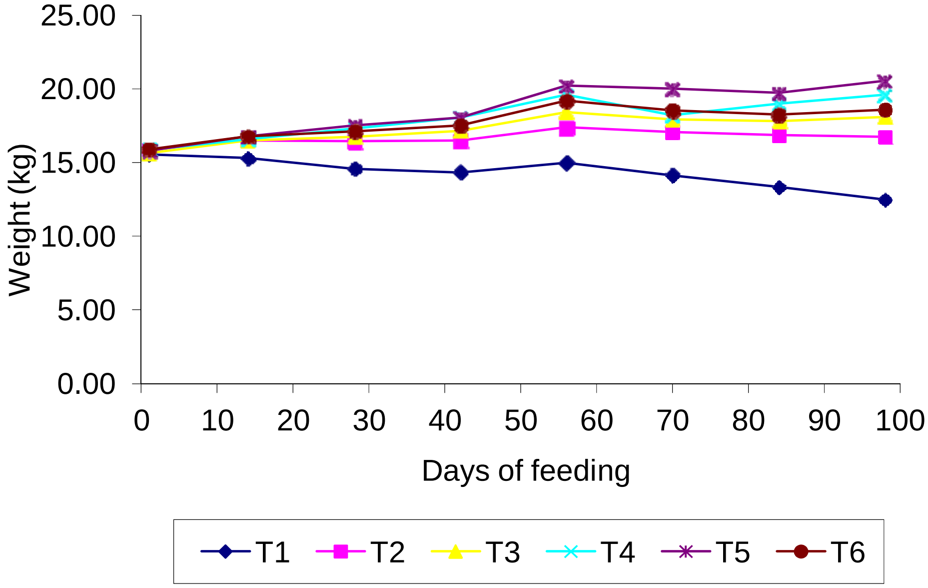

Figure 1. Trends in the live weight change of lambs.

Table 4. Apparent digestibility (g kg^{-1} DM) of nutrients in lambs maintained on urea treated or untreated wheat straw and supplemented with *L. leucocephala* foliage.

Treatment (n = 3)	DM	OM	CP	NDF	ADF	Ash	DE
T1	422^{d}	484^{c}	61^{d}	500^{b}	542^{c}	-117^{d}	411^{c}
T2	585^{b}	632^{a}	286^{c}	708^{a}	694^{a}	133^{bc}	595^{a}
T3	623^{ab}	659^{a}	477^{b}	716^{a}	694^{a}	245^{b}	617^{a}
T4	642^{a}	668^{a}	567^{a}	725^{a}	673^{ab}	411^{a}	632^{a}
T5	640^{a}	665^{a}	596^{a}	714^{a}	638.8^{b}	404^{a}	635^{a}
T6	502^{c}	549^{b}	552^{a}	521^{b}	426^{d}	42^{c}	515^{b}
SEM	16	14	19	13	15	43	16
Significance level treatment	***	***	***	***	***	***	***
T2 vs. T3, T4, T5	**	ns	***	ns	ns	***	ns
T2 vs. T6	***	***	***	***	***	ns	***
T5 vs. T6	***	***	ns	***	***	***	***

Means in the same column with different letters are statistically different (P<0.05), SEM=standard error of mean, ns = not significant, * = P<0.05, ** = P< 0.01, *** = P< 0.001.

g/day *leucaena*.

Nitrogen balance

Results of nitrogen balance study are presented in Table 5. There was significant variation (P<0.001) among treatments in nitrogen intake (NI), fecal nitrogen (FN), urinary nitrogen (UN) and nitrogen balance (NB). Urea treatment of wheat straw increased FN, UN and NB from 2.11 to 3.22, 0.85 to 1.41 and -0.71 to 0.038 g/day, respectively. With the exception of lambs on sole untreated wheat straw, lambs in the remaining treatments had shown positive NB, which increased with *leucaena* supplementation. The highest NB (2.27 g/day) was achieved at the highest NI observed in lambs fed on treated straw with 300 g/day *leucaena*, but was not different (P>0.05) from the group supplemented with 200 g/day *leucaena*. Expressed per g of N consumed, no remarkable difference (P>0.05) in NB was observed among the supplemented lambs. There was no difference (P>0.05) in NB between lambs consumed treated straw with 100 g/day *leucaena* (0.038 g/day) and lambs on sole treated straw (0.561 g/day); but was higher (P<0.001) in the former than the latter when expressed per unit nitrogen consumed (-0.034 versus 0.06 g gNI^{-1}). Similarly,

Table 5. Nitrogen balances in lambs fed on urea treated or untreated wheat straw with or without *leucaena* foliage supplementation.

Treatment (n = 3)	NI (g/day)	Nitrogen excreted					NB	
		FN		UN		Total	(g/day)	(g g^{-1} NI)
		(g/day)	(g g^{-1} NI)	(g/day)	(g g^{-1} NI)	(g/day)		
T1	2.26[f]	2.11[f]	0.93[a]	0.85[d]	0.37[cd]	2.97[f]	-0.71[c]	-0.31[c]
T2	4.68[e]	3.22[e]	0.71[b]	1.41[d]	0.32[d]	4.64[e]	0.038[bc]	-0.034[b]
T3	8.32[d]	4.32[d]	0.52[c]	3.43[c]	0.41[bc]	7.76[d]	0.561[b]	0.060[a]
T4	12.20[c]	5.27[c]	0.43[d]	5.09[b]	0.41[bc]	10.37[c]	1.829[a]	0.146[a]
T5	15.55[a]	6.30[a]	0.40[d]	6.98[a]	0.44[ab]	13.28[a]	2.266[a]	0.149[a]
T6	13.02[b]	5.83[b]	0.44[d]	6.51[a]	0.49[a]	12.35[b]	0.675[b]	0.052[ab]
SEM	0.16	0.15	0.018	0.21	0.02	0.28	0.263	0.030
Significance treatment	***	***	***	***	***	***	***	***
T2 vs. (T3, T4, T5)	***	***	***	***	***	***	***	***
T2 vs. T6	***	***	***	***	***	***	ns	*
T5 vs. T6	***	*	ns	ns	ns	*	***	ns

NI = nitrogen intake, FN = fecal nitrogen, UN = urinary nitrogen, NB = nitrogen balance, SEM = standard error of mean, n = number of lambs used in each treatment.

lambs supplemented with 300 g/day *leucaena* on untreated straw (T6) showed higher (P<0.001) NB compared to lambs on sole treated straw (T2), when expressed per unit supplement consumed (0.052 versus -0.034 g gNI^{-1}). Generally, the magnitudes of NB (g/day) were proportional to the trend of live weight changes of sheep indicating positive gains of sheep associated with positive NB and vice versa.

Fecal nitrogen and UN excretions increased (P<0.001) with straw ammoniation and *leucaena* supplementation. The highest FN loss (6.3 g/day) was attained in lambs fed on urea treated straw with 300 g/day *leucaena*; whereas, the highest UN losses (6.98 and 6.51 g/day) were observed in lambs supplemented with 300 g *leucaena* on treated and untreated straws. Expressed per unit of NI, FN loss was highest in lambs fed on untreated straw alone. However, UN loss was lowest in lambs consumed either sole untreated or urea treated straw and increased significantly (P<0.001) with increased supplementation.

DISCUSSION

The present increase in CP contents of wheat straw with urea treatment is lower than the reported 448.7% (Abebe et al., 2004) and 122.8% (Sahoo et al., 2002) increment. These differences could be attributed to loss of ammonia nitrogen during aeration before fed to lambs. Sundstøl and Coxworth (1984) reported that up to two-third of the ammonia generated could be lost associated with aeration before feeding and at storage condition. Similar to the present finding, increased in CP, but reduced NDF and ADF contents of urea treated wheat straw (Abebe et al., 2004; Kjos et al., 1987) and maize stalks, husks and cobs (Oji et al., 2007) have been reported. However, Sahoo et al. (2002) reported increased NDF and ADF contents of urea treated wheat straw, while Habib et al. (1998) reported increased NDF, but decreased ADF contents of wheat straw varieties in response to urea treatment. The reduction in fiber fraction due to ammoniation is attributed to the release of hemicellulose and lignin fractions (Theander and Aman, 1984). A slight increase (2.3%) in gross energy (GE) content of treated straw over untreated straw could be due to the energy value of the generated ammonia. The observed increase in nutrient intake with straw urea treatment and supplementation could be resulted from an increase in the apparent digestibility of nutrients (Table 4). This indicates a useful additive effect of supplementation and urea treatment in enhancing feed values of poor quality roughages. Increase in roughage intake has been reported to result from improved rate and extent of digestion in rumen elsewhere (Chesson and Orskov, 1984; Ørskov, 1987).

Higher intake of wheat straw was noticed in lambs supplemented with 300 g/day *leucaena* compared to lambs on sole untreated straw, which could be due to improved rumen fermentation and nutrient availability. Abdu et al. (2012) reported that DM intake in Yankasa bucks fed urea treated maize stover increased with *Ficus sycomorus* leaf supplementation. Previous studies (Bonsi et al., 1996; Kaitho et al., 1998; Nigussie et al., 2000; Solomon, 2002) on *leucaena* foliage supplementation to sheep fed poor quality roughages are in agreement with the present finding. Moreover, increased feed DM intake, digestibility and live weight change of Ethiopian highland sheep supplemented with graded levels of protein rich concentrates on urea treated wheat straw (Gebretsadik and Kebede, 2011) and urea treated rice straw (Hailu et al., 2011) were reported. Results in this study are in agreement with that reported for beef cattle fed on urea treated rice straw without supplementation (Promma et al., 1983), but was contrary to the findings of

Hadjipanayiotou et al. (1993) who reported that Awassi sheep fed on sole urea treated barley straw did not meet their maintenance requirements. Similarly, the higher live weight gain of sheep fed on treated straw with supplement came to support the results of previous works (Flores et al., 1979; Kaitho, 1997) suggesting that *leucaena* supplementation promotes microbial protein synthesis and/or provides by-pass protein that post ruminally digested and absorbed.

Khanal et al. (1999) reported 18.1 and 13.3% increment in apparent DM digestibility of urea treated rice and wheat straw compared to untreated straw. The higher the digestibility of ammoniated roughage over untreated straw may imply the effectiveness of treatment process. Increased DM digestibility due to straw urea treatment in this study is comparable with the reported DM degradability (556 kg^{-1} DM) for urea treated wheat straw (Mengistu and Uden, 2001), and is about 1% higher than the suggested 10 to 15% increment when ammoniation is effective (SundstØl et al., 1978). However, as much as 20% improvement in digestibility of poor quality roughages could be expected up on ammoniation (FAO, 2002). The present low CP digestibility for the treated and untreated straw far below the expected level was probably due to the observed low protein content and increased fecal nitrogen loss. The low CP digestibility for untreated straw was in agreement with previous work (Hassen and Chenost, 1992). Moreover, Reddy and Reddy (2002) and Tumbare et al. (2001) reported increased CP digestibility of wheat straw (untreated versus urea treated) from 2.36 to 3.86% and 5.35 to 6.93%, respectively. In agreement with present result, improved digestibility of wheat straw NDF and ADF due to urea treatment were reported in other studies (Sahoo et al., 2002; Can et al., 2004; Moss et al., 1994). The negative digestibility value (-11.7%) of total ash in lambs fed on untreated straw alone may be due to low mineral content of straw and/or biased by excretion of body minerals at gut level.

Positive NB was also reported in sheep fed ammonia treated rice straw (Elseed, 2004) and urea treated wheat straw retaining 1.67 g N per day (Sahoo et al., 2002). Similar to the present findings, Yankasa bucks supplemented with ficus foliage as a protein source on urea treated maize stover has improved (117.7% over unsupplemented) protein retention (Abdu et al., 2012). The increase in nitrogen loss with increased supplementation would imply inefficient utilization of nitrogen probably because of insufficient energy substrate matching available nitrogen, and/or the high proportion of NDF bound nitrogen in LL foliage contributing to fecal nitrogen loss (Kaitho et al., 1998). Hove et al. (2001) observed a higher FN loss (615 g kg^{-1} NI) than UN loss (85 g kg^{-1}) upon supplementing sun dried *L. leucocephala* foliage to goats fed on pasture hay, and also reported similar findings in goats supplemented with *Acacia angustissima* and *Calliandra calothyrsus* foliages. The higher fecal N, but lower UN excretion may also result from feeding condensed tannin-rich legumes, as it binds dietary protein and makes indigestible in rumen (Hindrichsen et al., 2004).

Conclusion

In this study, urea treatment improved wheat straw chemical composition, nutrient intake, digestibility, nitrogen balance and growth of lambs. Supplementation of LL foliage hay to growing lambs maintained on urea treated straw enhanced nutrient utilization and animal performance, indicating that combined use of urea treatment and foliage supplementation has synergistic effect in improving nutritive values. The two strategies could be used in combination, as an alternative method to improve the nutritional values of poor quality roughages.

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