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*Full Length Research Paper*

# Effect of varying levels of groundnut (*Arachis hypogaea*) haulms on the growth performance of weaners rabbits (*Oryctalagus cuniculus*)

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**Thirty two, 6 to 8 weeks old rabbits of mongrel origin, balanced for sex and weighing averagely 0.92 kg were allotted to four dietary treatments in a complete randomized design (CRD) with 8 rabbits per treatment. The diets contained groundnut haulms (GH) at 40, 50, 60 and 70% levels of inclusion with a crude protein content of 16%. The rabbits were fed for eight weeks with 6 weeks of preliminary feeding and 2 weeks of faecal collection. Data collected were subjected to analysis of variance (ANOVA). The results obtained indicated an increase in feed conversion ratio (FCR), acid detergent fiber digestibility (ADFD), crude protein digestibility (CPD) and feed cost (=N=) / kg weight gain (FC/WG), and a decrease in dry matter intake (DMI), dry matter digestibility (DMD), daily weight gain (DWG), crude protein digestibility (CPD) and digestible dry matter intake (DDMI) with increasing fibre level. There was a significant difference (P<0.01) among the mean values for acid detergent fibre intake (ADFI) and digestible acid detergent fibre intake (DADFI) indicating that these variables were affected by fibre levels. All the rabbits fed on the four diets gained weight. Taking into consideration feed cost and the availability of grains as a limiting factor to increase animal production, it can be concluded that GH, a potential crop residue can be included in the diet of growing rabbits at up to 70% level, since this did not cause any significant deleterious effect on the growth and performance of the rabbits.**

**Key words:** Groundnut haulms, growth, performance, rabbits.

## INTRODUCTION

Crop residue will increasingly become the dominant feed resource for livestock, especially in most Savannah ecosystems where more and more rangelands are being converted into crop lands. Projections of demand and supply of livestock products in Sub Saharan Africa (SSA) are daunting just as for cereals. Milk output must

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increase from the 1988 level of approximately 8.2 million tons to 35.6 million tons by 2025, a 4% compound annual growth rate. Similarly, meat output must expand at a 3.4% compound annual growth rate from 3.2 million tones in 1988 to 11.2 million tons in 2025 (Winrock International, 1992). Meat production in Africa has been on the decline since 1960 and unless urgent actions are taken to increase or sustain animal products, the much needed animal protein supply will soon disappear from most family menus (Nuru, 1988). More than 42% of the total present populations of SSA live in West Africa with Nigeria having the largest population (Winrock International, 1992). Thus, the tremendous challenges facing livestock production in SSA and Nigeria in particular is to generate a sustainable feed supply response which can match the expected demand.

The human population in Nigeria stands at 173.6 million and is growing at the rate of 2.8% per annum (PRB, 2013), much faster than the animal supply growth rate of 1.9% (Adegbola, 1998). The per capita consumption of animal protein in Nigeria at present stands below 9 g per day as compared to over 50 g per day in North America and Europe (Boland et al., 2013). There is therefore a protein: calorie deficiency in Nigeria resulting in malnutrition, whose common effects can be very debilitating especially on children (NRC, 1991). In poor countries, even the middle class eat less meat in a year than the population of North America and Europe eat in a month (Winrock International, 1992). The break through in livestock production in these countries is attributed to the use of surplus grains and rich oil seed cakes to meet the nutritional requirement of the animals. In Nigeria, there is no grain surplus and cereals such as sorghum, maize and millet form the staple food of the populace and therefore cannot be used at the required level for feeding animals (Umunna and Maisamari, 1981). Faced with the shortage of grains and the zeal to bridge the gap in animal protein consumption, it becomes necessary to search for economical feed stuffs, cheap, easy and readily available such as crop residues and agro-industrial by-products, which can be used to feed animals for sustainable production (Alhassan, 1988; Okaiyeto, 1984).

Rabbit production exemplifies the vast possibilities for increasing meat production in the most poverty stricken parts of the world. This is due to its high fecundity, fast growth rate, short generation interval and low feed cost. The rabbit's capacity for reproduction is legendary. A single male and four females can produce as many as 3,000 offspring a year, representing some 1,450 kg of meat - as much as an average sized cow (Oyawoye, 1989). The meat of rabbit is nutritious, all white, fine grained and appetizing, and has more protein and less fat, cholesterol, sodium and calories per grain than beef, pork, lamb or chicken (NRC, 1991; Oyawoye, 1989). It is therefore the meat of choice for coronary heart patients. With a dressing percentage of 74%, the rabbit meat is the perfect size for family consumption, requiring no special preservation like drying, curing, or refrigeration. Other important products of rabbits include the fur and pelt which are used in making garments as well as the feet and tails used in good luck charms and many other curios (NRC, 1991). The ability of rabbit to effectively utilize fibrous feedstuffs that cannot be consumed by humans, gives them their potential as an emerging meat and fur producing animal. Taking into consideration feed cost as a limiting factor in livestock production, the rabbit stands out unique because it does not compete directly with man for the scarce grains available. The objective of this study therefore was to evaluate the performance of rabbits fed groundnut haulms, a potential legume crop residue in Nigeria, as a source of fibre at levels of 40, 50, 60 and 70% inclusion in the diets.

## MATERIALS AND METHODS

### Study area

The study was carried out in Bauchi State which occupies the centre of the Northern Region in the sudan savannah (arid and semi- arid) ecological zone of Nigeria. Its centre is on latitude $10°19^{1}$ and longitude $90° 49^{1}$ at an altitude of 590 m above sea level. There are two distinct seasons in a year: the rainy season (between May- October) and dry season (between November-April). The mean annual rainfall is 1091 mm. Detailed climatic description of Bauchi is well documented (Butswat, 1994).

### Diets

Four diets were formulated using groundnut haulms at varying levels of 40, 50, 60, and 70% in each diet. The groundnut haulms were ground and mixed together with maize and groundnut cake. Table 1 shows the formulated diets and their chemical composition. The diets were in mash form.

### Experimental rabbits and management

Using the completely randomized design, 32 adapted exotic breed of rabbits of mongrel origin, balanced for sex, were allotted to four dietary treatments with eight rabbits per treatment. The rabbits had an average weight of 0.92 kg and were 6 to 8 weeks old. They were dewormed and given antibiotics prior to the commencement of the experiment. Each rabbit was housed in a metabolic cage, fitted with a catch tray beneath for easy collection of clean faeces void of urine contamination. Each rabbit was provided with 100 g of the diet in mash form in a specially manufactured metal feed trough to minimize feed wastage and 500 mls of water at 7.00 h daily. Feed refusals were collected and weighed the next morning to determine the actual quantity of feed consumed before providing fresh feed. The rabbits were fed for eight weeks, and faeces were collected on the 7$^{th}$ and 8$^{th}$ week. Data was collected for:

1. Feed intake variables (dry matter intake, crude protein intake, water intake and acid detergent fiber intake);
2. Growth and performance variables (feed cost =N= /kg weight gain, daily weight gain and feed conversion ratio);
3. Digestibility of nutrients (dry matter digestibility, crude protein digestibility and acid detergent fiber digestibility);
4. Digestible nutrient intake (digestible dry matter intake, digestible crude protein intake and digestible acid detergent fiber intake);

**Table 1.** Composition of the experimental diets.

| Ingredients (%) | Diets | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| | **40%** | **50%** | **60%** | **70%** |
| Maize | 37.79 | 28.90 | 19.58 | 10.31 |
| Groundnut cake | 19.21 | 18.10 | 17.42 | 16.69 |
| Groundnut Haulms | 40.00 | 50.00 | 60.00 | 70.00 |
| Bone meal | 2.00 | 2.00 | 2.00 | 2.00 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 |
| *Vitamin / mineral premix | 0.50 | 0.50 | 0.50 | 0.50 |
| **Total** | 100 | 100 | 100 | 100 |

*Vitamin/Mineral premix composition per kg diet: Vitamin A, 3,200,000 iu; Vitamin D3, 1,200 iu; Vitamin E, 3,200 iu; Vitamin $K_3$, 800 mg; Vitamin $B_1$, 400 mcg; Selenium (Se), 40 mg; Manganese (Mn), 32,000 mg; Pantothenic acid, 2000 mg; folic acid, 200 mg; Chlorine chloride, 60,000 mg; Iron (Fe), 8,000 mg; Copper (Cu), 3,200 mg; Zinc (Zn), 200 mg; Cobalt (Co), 90 mg; Iodine (I), 800 mg

**Table 2. C**hemical composition of the diets (%).

| Parameter | Diets | | | |
|---|---|---|---|---|
| | **40%** | **50%** | **60%** | **70%** |
| Dry matter | 96.66 | 96.77 | 96.95 | 96.90 |
| Crude protein | 15.96 | 15.56 | 16.19 | 16.50 |
| Acid detergent fibre | 19.58 | 22.94 | 26.72 | 29.83 |
| Ash | 7.73 | 8.34 | 9.30 | 11.35 |

#### Chemical analysis

Feed samples from each diet and faeces collected separately for each rabbit were oven dried for 48 h at 105°C. The faeces were then ground and both feed and faeces were stored in separate labeled sample bottles. Proximate analysis was done by the AOAC (1980) methods for the estimation of crude protein and ash, while the acid detergent fibre was determined by the method of Goering and Van Soest (1970). Table 2 shows the composition of the chemical analysis of the diets.

#### Statistical analysis

The data collected for each parameter were subjected to analysis of variance (ANOVA). Significant differences among means were determined by least significant difference (LSD) test (Steel and Torrie, 1983).

## RESULTS AND DISCUSSION

Results on the effect of level of GH inclusion on nutrient intake, feed cost/kg weight gain and growth performance of rabbits fed on the different diets is shown in Table 3. There was no significant difference in the means of all the nutrient intake variables except for ADFI (P<0.01). The ADFI values ranged from 10.11 g on the 50% GH diet to 19.28 g on the 70% GH diet. The nutrient digestibility percentage of all the diets is recorded in Table 4. No significant difference was recorded for the dry matter, crude protein and acid detergent fiber digestibility. Among the digestible nutrient intake variables, highly significant difference (P<0.01) was observed for DADFI and not for the other variables (Table 5). The values ranged between 3.81 g/day on the 50% GH diet to 8.00 g on the 70% GH diet.

There was a decrease in dry matter intake (DMI) with increasing fibre levels which is at variance with the reports of Butcher et al. (1981) and Abour-Ashour and Barakat (1986). The DMI was in the range of 4.8 to 5% of their body weight and therefore comparable with the range of 4 to 7% reported by Reddy et al. (1977) for rabbits under temperate conditions. The DMI values obtained were similar to those of Aduku et al. (1986). Deblas et al. (1981) reported that the crude fibre of a diet had a significant effect on the DMI. They found a linear increase in the DMI of 2.97 g per day with each unit increase in crude fibre. Rabbits eat more of pelleted feed than feed in mash form. Reports have shown that rabbits ate 35% more feed and gained 60% more weight on pelleted feed than on mash diets (Reddy et al., 1977), and this might have been responsible for the low DMI, although there was any significant difference.

Crude protein intake (CPI) depends on the crude protein of the diet, nature of the diet and environmental

**Table 3.** Effect of level of groundnut haulms on nutrient intake and performance of Weaners' rabbits.

| Parameter | Diets | | | | | |
|---|---|---|---|---|---|---|
| | **40%** | **50%** | **60%** | **70%** | **S.E** | **LOS** |
| DMI(g) | 65.04 | 63.44 | 59.63 | 63.57 | 2.40 | NS |
| CPI (g) | 10.37 | 9.87 | 9.65 | 10.46 | 0.38 | NS |
| ADFI(g) | 12.74 | 10.11 | 15.93 | 19.28 | 0.54 | ** |
| DWI(ml) | 370.44 | 387.80 | 309.48 | 322.00 | 19.33 | NS |
| FCR | 5.24 | 6.12 | 7.14 | 7.49 | 0.79 | NS |
| DWG (g) | 12.68 | 10.85 | 8.64 | 9.01 | 1.18 | NS |
| FC(=N=)/kg WG | 218.52 | 240.64 | 256.72 | 261.04 | 28.24 | NS |

DMI: Dry matter intake; CPI: Crude protein intake; ADFI: Acid detergent fibre intake; DWI: Daily water intake; FCR: Feed conversion ratio; DWG: Daily weight gain; FC (=N=)/KgWG: Feed cost in naira per kilogram weight gain; ** - P<0.01; NS: Not Significant; LOS: Level of Significance.

**Table 4.** Mean and Standard error of nutrient digestibility (%) in weaner rabbits fed on graded levels of GH

| Parameter (%) | Diets | | | | | |
|---|---|---|---|---|---|---|
| | **40%** | **50%** | **60%** | **70%** | **S.E** | **LOS** |
| DMD | 63.41 | 63.13 | 62.45 | 64.89 | 2.71 | NS |
| CPD | 72.09 | 67.73 | 71.51 | 71.16 | 3.12 | NS |
| ADFD | 39.74 | 37.53 | 41.12 | 41.57 | 1.96 | NS |

DMD: Dry matter digestibility; CPD: Crude protein digestibility; ADFD - Acid detergent fibre digestibility.

**Table 5.** Mean and standard error of digestible nutrient intake (g/day) in weaner's rabbits fed graded levels of GH.

| Parameter (g/day) | Diets | | | | | |
|---|---|---|---|---|---|---|
| | **40%** | **50%** | **60%** | **70%** | **S.E** | **LOS** |
| DDMI | 41.03 | 40.03 | 37.46 | 39.26 | 2.51 | NS |
| DCPI | 7.48 | 6.67 | 6.96 | 7.46 | 0.47 | NS |
| DADFI | 4.94 | 3.81 | 6.80 | 8.00 | 0.33 | ** |

DDMI: Digestible dry matter intake; DCPI – Digestible crude protein intake; DADFI – Digestible acid detergent fibre intake; ** - P< 0.01; NS - Not significant; LOS - level of significance.

effects. The CPI obtained in this study was lower than the values stipulated by the NRC (1977) for rabbits under temperate conditions. The CPI ranged from 9.65 to 10.46 g/day and is comparable to those reported by Doma (1994). The low CPI might have been due to the low DMI of the diet caused by the nature of the diet and high ambient temperatures of the sub-humid tropics. High ambient temperatures have an adverse effect on voluntary feed intake by causing stress and discomfort (Anonymous, 1972). Despite the slightly higher crude protein intake by the rabbits in diet 4, its effect could not be felt because of the high fiber content of the diet thereby masking its digestibility and eventual utilization (Table 3).

Acid detergent fiber intake (ADFI) of rabbits on diet 4 (70% GH diet) was significantly (P<0.01) higher than those for the other diets, thus revealing that ADFI was influenced by the level of inclusion of GH in the diet. This is in agreement with the report of Spreadbury and John (1978), who stated that feed consumption increased with increase in the ADF of the diet. The values ranged from 10.11 g/day on the 50% GH diet to 19.28 g/day on the 70% GH diet.

Water Intake (WI) is a function of the nature of diet, age of the animal and ambient temperature; the drier the diet the more water is consumed. Generally, literature information on water intake estimates is scarce because in most experiments, water is usually given *ad libitum*. The WI ranged from 309.48 ml per animal per day on the 60% GH diet to 387.80 ml on the 50% GH diet. Cheeke and Patton (1987) reported that rabbits drank about 120 mls per kg at 70 days of age and the amount decreased to about 64 ml at 340 days under environmental temperature of 28°C. They also observed that when temperature drops to 9°C, water intake was 76 ml and decreasing to 46 ml per kg of feed consumed.

Rabbits on all four diets gained weight. The daily weight gain (DWG) ranged from 8.64 g/day on the 60% GH diet to 12.68 g/day on the 40% GH diet. These values were lower than 17.4 g/day reported by Aduku et al. (1986) for rabbits fed groundnut haulm diets, 41.1 g/day reported by Pote et al. (1980) for exotic breed of rabbits feed 50% alfalfa and 19.1 g ADF diets under temperate conditions and 45.1 g/day obtained by Harris et al. (1984) on diets containing 40% *Desmodium*. The trend in DWG observed among the mean values of the diets is in agreement with the findings of Spreadbury and John (1978), who stated that rabbits performed better on a low fibre than on a high fibre diet. The low values obtained in our study may be due to low DMI, genetic as well as environmental effects.

The feed conversion ratio (FCR) is an index of the efficiency of converting unit feed into unit weight gain (Feed/gain). There was an increase in the FCR with increasing fibre level though this was not significant. The increase is in agreement with the findings of Pote et al. (1980). Alawa and Amadi (1991) observed that rabbits consume more of a high fibre diet to compensate for the low energy content of such a diet. The FCR of 5.24 on the 40% GH diet was higher than 3.20 observed by Pote et al. (1980) on 40% alfalfa- based diet.

Feed cost per kg weight gain is an estimate of the cost in naira of the quantity of feed required to obtain a kilogram weight of rabbit meat. The lowest value was observed on the 40% GH diet (218.52 naira) and the highest value of 261.04 naira was recorded on the 70% GH diet. These differences were, however, not significant.

Digestibility is a measure of that portion of a feed which is not recovered in the faeces and is therefore considered to have been absorbed and assimilated that is, put into use by the animal (Ositelu, 1980). The dry matter digestibility (DMD) of the diets ranged from 62.46% on the 60% GH diet to 68.89% on the 70% GH diet. The 40% and 50% GH diets had similar DMD's of 63.14% and 63.13% respectively. The DMD value obtained on the 40% GH diet was lower than those obtained by Doma (1994) on 40% Cowpea Shells (CPS) and 40% Maize Cobs (MC) diets which were 67.74 and 67.38% respectively. The trend obtained in DMD was similar with the findings of Adegbola and Akinwande (1981) who reported a decrease in DMD with increasing fibre level.

The crude protein digestibility (CPD) of the diets was fairly high, ranging from 67.73% on the 50% to 72.09% on the 40% GH diets respectively. The high CPD is in agreement with the report of Ekpenyong (1986), who observed that rabbits are able to digest non-fibre bound protein in fibrous materials as much as in cattle and even utilizing it more efficiently since the protein will not be broken down into ammonia as is the case in the rumen. The CPD value of 72.09% observed on the 40% GH diet was comparable to 71.62% obtained by Doma (1994) on 40% CPS diet. The decrease in CPD with increasing fibre level is in agreement with the findings of Esonu and Udedibie (1993), who attributed this to increasing metabolic faecal nitrogen and the masking effect of fibre on protein digestion.

The acid detergent fibre digestibility (ADFD) ranged from 37.53% on the 50% to 41.57% on the 70% GH diets, indicating an increase with increasing fibre level. The increase is at variance with the findings of Esonu and Udedibie (1993) and Adegbola et al. (1985). Rabbits are much less able to digest fibre than ruminants, since fibre digestion in rabbits is post gastric. Rabbits are hindgut fermenters, selecting and retaining small rather than large particles. Normal peristaltic movements propel the large, less dense fibre particles through the colon while contraction of the haustra of the colon moves fluids and small particles in a retrograde manner to the Caecum (Oyawoye, 1989). Cheeke et al. (1986) reported that fibre is poorly digested in the rabbit because it is rapidly propelled through the colon and excreted as hard faeces. The rabbit tends to ignore the fibre and concentrate on the 75 to 80% non-fibre fraction which is retained for prolonged period in the caecum, allowing extensive fermentation. They concluded that caecotrophy in rabbits is more important in the digestion of forage protein than fibre utilization due to selective retention of non-fibre components in the caecum. Spreadbury and John (1978) concluded that for optimum growth, it is advisable to maintain the level of ADF in the diet above 50 g and preferably at about 100 g ADF per kg of diet. They also found that feed consumption increased from 80g to 115 g/day as the ADF concentration in the diet increased from 39 to 270 g ADF per kg, and recommended 140 g per kg for growing rabbits and up to 250 g per kg for replacement of breeding stock in their later stages of growth. The ADF of the diets ranged from 19.58% on the 40% GH diet to 29.83% on the 70% GH diet (Table 2), representing 195.8, 229.4, 267.2 and 298.3 g of ADF per kg on the 40, 50, 60 and 70% GH diets respectively.

The highest digestible dry matter intake (DDMI) of 41.03 g was obtained in rabbits fed 40% GH diets and the lowest value of 37.46 g on the 60% GH diet, indicating a decrease in DDMI with increasing fibre level. The DDMI of 41.03 g obtained on the 40% GH diet was comparable to 43.33 g obtained by Doma (1994) on 40% CPS based diets. The DDMI is related to the DMI and the nature or quality of the diets. In this experiment, the diets were fed in mash rather than pellet form. The digestible crude protein intake (DCPI) was similar for the 40 and 70% GH diets being 7.48 and 7.46 g/day as well as for the 50 and 60% GH diets being 6.69 and 6.96 g/day respectively. Despite the high crude protein content of the

60 and 70% GH diets (16.19 and 16.50% respectively), the digestible crude protein intake did not reflect correspondingly because of the low digestible energy of the diets resulting from the high fibre causing inefficient protein utilization. The DCPI of the 40%, 50 and 70% GH diets represented 11% of the feed consumed while the value for the 60% GH diet was 12%. These results are in agreement with NRC (1977) values, which gave estimates of digestible protein (DP) requirement for growth of rabbits as 11 to 12% of the diets consumed. The digestible acid detergent fibre intake (DADFI) ranged from 3.81 g on the 50% GH diet to 8.00 g on the 70% GH diet respectively, thus revealing an increase in DADFI with increasing fibre level. There was a significant (P<0.01) effect on the DADFI, indicating that DADFI of the diets depended on the level of inclusion of groundnut haulms. The DADFI of the 70% GH diet was significantly higher than that of the other diets. These values are comparable to those reported by Doma (1994). The low values obtained for DADFI indicates that acid detergent fibre is less digestible, probably due to its high lignin content. Champe and Maurice (1983) reported that rabbits require crude fibre in excess of 9% to reduce the incidence of enteritis, whilst high fibre levels in excess of 20% may lead to caecal impaction and limit energy intake. Cheeke et al. (1986) stated that dietary fibre level for rabbits should be in the range of 15 to 20%. The fibre levels in this experiment ranged from 19.58% on the 40% GH diets to 29.83% on the 70% GH diet (Table 2). Juan and Stahh (1982) stated that inclusion of forage in the diets of rabbits greatly economizes the amount of concentrate feed needed.

## CONCLUSION AND RECOMMENDATIONS

On the bases of the above findings, the 40% GH diet gave better results for most of the parameters studied, though with no significant difference. Thus, we can conclude that, groundnut haulms can be added to rabbit diets at up to 70% level, taking into consideration that the availability of concentrates or grains is the limiting factor to increased animal production. Therefore, it can be recommended that groundnut haulms may be added at up to 70% in rabbit diets since this level did not cause any deleterious effect or significant depression in daily weight gain and feed conversion efficiency in the weaner rabbits under study.

## Conflict of Interests

The author(s) have not declared any conflict of interests.

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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

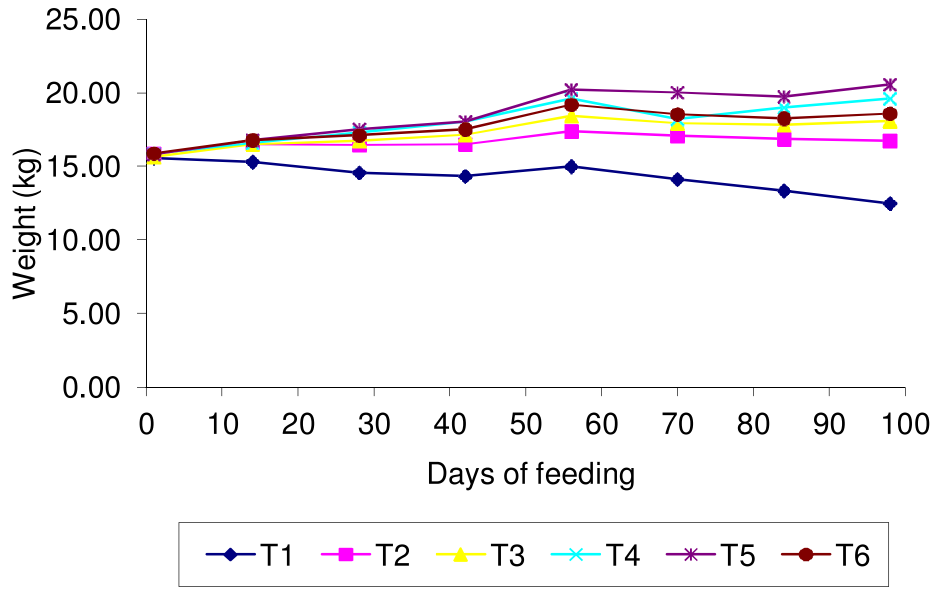


**Figure 1.** Trends in the live weight change of lambs.

**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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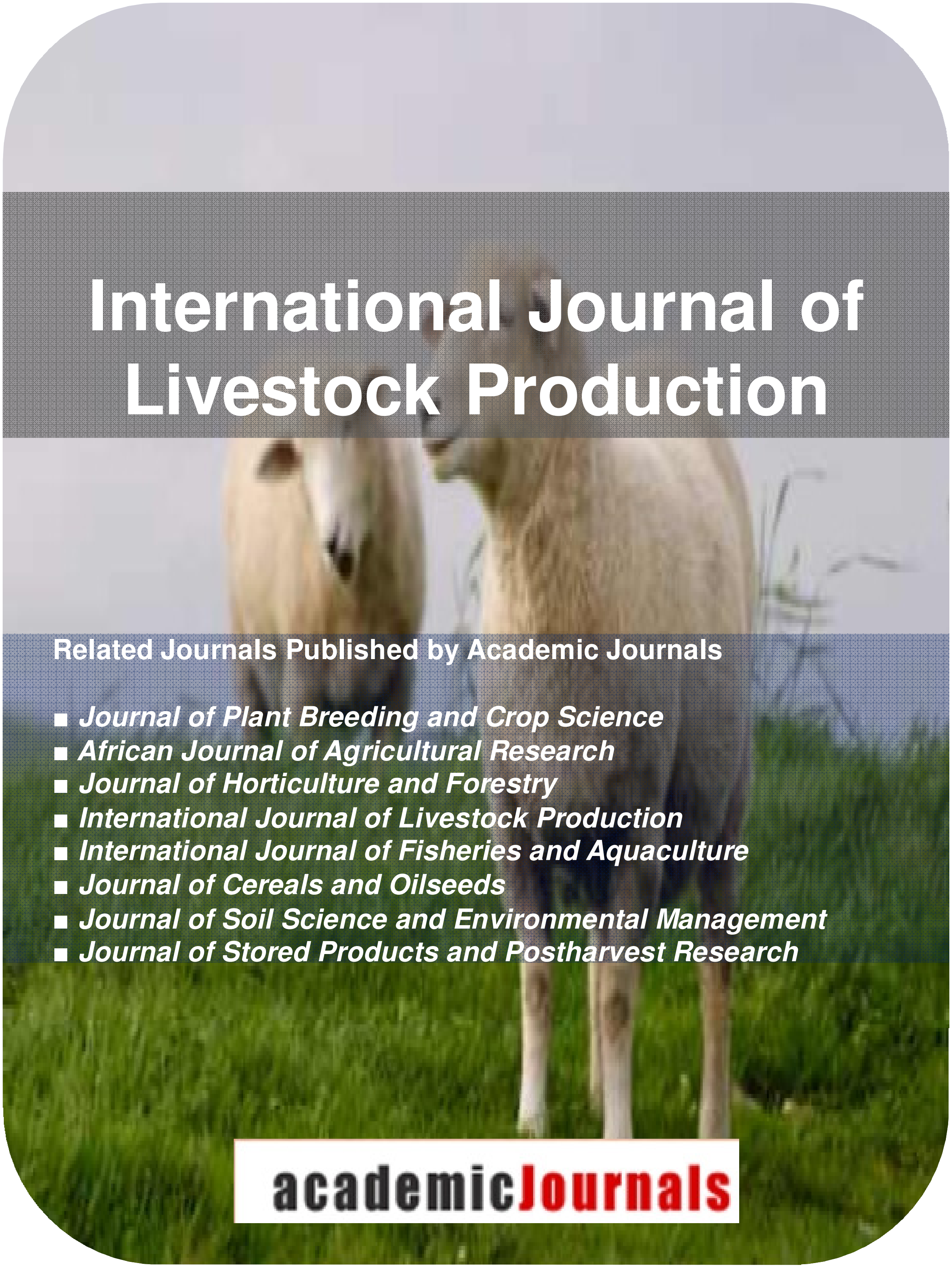
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