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Effect of Supplementation with Different Proportion of Concentrate Mixture and Untreated or Calcium Hydroxide Treated *Acacia toritilis* Leaves on Feed Intake, Digestibility, Nutrient Retention and Rumen Fermentation Parameters of Arsi-Bale Goats Fed Rhodes Grass Hay Basal Diet

Research Article

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ABSTRACT

An experiment was conducted to examine the effect of replacing a concentrate supplement with untreated or calcium hydroxide (3% w/w) treated *Acacia toritlis* leaves in Rhodes grass (*Chloris gayana*) hay basal diets on feed intake, digestibility, nutrient retention and rumen fermentation parameters of 54 yearling male goats of *Arsi-Bale* breed (body wt of 13.78 ± 1.9 kg and 12 months old). The experiment was conducted for 84 days in a 2 × 5 factorial design (factor 1: alkali treatment of leaves (treated or untreated) and factor 2: five levels of leaves in concentrate mixture). The treatment diets were: UL-0: hay + 300 g concentrate mixture; UL-25: hay + 225 g concentrate and 75 g untreated dried leaves, UL-50: hay + 150 g concentrate and 150 g untreated dried leaves; UL-75: hay + 75 g concentrate and 225 g untreated dried leaves; UL-100: hay + 300 g untreated dried leaves; TL-0: hay + 300 g concentrate; TL-25: hay + 225 g concentrate and 75 g treated dried leaves; TL-50: hay + 150 g concentrate and 150 g dried treated leaves; TL-75: hay + 75 g concentrate and 225 g treated dried leave and TL-100: hay + 300 g treated dried leaves. Both $Ca(OH)_2$ treatment and partial replacement of the concentrate mixture by Acacia leaf meal (ALM) significantly ($P<0.05$) reduced ether extract (EE), total phenolics (TP), total tannins (TT) and CT contents of the diets. Whereas, dietary concentrations of ash, acid detergent fibre (ADF), acid detergent lignin (ADL) and calcium (Ca); intakes of dry matter (DM), crude protein (CP), neutral detergent fibre (NDF), nitrogen, Ca and P; digestibility of DM, organic matter (OM), CP and NDF; concentration of rumen ammonia nitrogen and pH of the rumen fluid were significantly ($P<0.05$) increased by the alkali treatment and partial replacements. In general comparable results of intake, digestibility and balances of nutrients were observed when concentrate ration in the diets was replaced by treated ALM at 75% and untreated 50% in order of importance against untreated leaf meals. It is concluded that partial replacement of acacia leaf meals in the concentrate mixture combined with calcium hydroxide treatment at 75% level gave maximum benefits to goats than other levels of untreated or treated leaves.

KEY WORDS Acacia leaf meal, nitrogen and mineral balances, phenolic composition, rumen ammonia concentration.

INTRODUCTION

In arid and semi arid regions of Ethiopia, livestock are kept under extensive management system and depend on rangeland pastures that are often deficient in nitrogen and digestible nutrients. These low quality feeds reduce intake,

digestion and utilization of nutrients. Most legume trees and shrubs have high protein content, which makes them promising supplements and are practical solution to alleviate nutrient deficiencies in poor quality natural pastures.

However, the majority of these feed resources have one or more anti-nutritional factors which adversely affect the performance of animals when fed without treatment particularly at higher levels in the diets for long periods (Kumar, 2011; Amita, 2014). Tannins are very complex plant secondary metabolites which can precipitate protein, carbohydrates and other macronutrients (Barman and Rai, 2008; Hameed, 2011).

The harmful effects of tannins are depression of feed intake, digestibility and nutrient utilization, reduction in growth and production rate, toxicity and even death depending on the type and age of animals, type and level of tannins in the feeds, biological activity of tannins, level of tannin intake and quality of basal diets (Makkar, 2003a; Amita, 2014).

Acacia trees are common in the drier areas of Ethiopian rangelands and are rich in protein and digestible nutrients (Shimelis, 2010; Abebe, 2010). *Acacia toritlis* (Forssk) Hayne is one of the dominant Acacia species present in vast areas of Afar and Borana rangelands. It is a small to medium-sized evergreen tree or shrub that grows up to 21 m tall; well-developed multiple stemmed with a flat-topped or rounded and spreading crown; dark grey to black colored browse mainly fed by camel, goats and wild herbivores. This species is an important source of fodder for cattle in India, west Africa, Somalia and Ethiopia. The leaves are fed green as well as dry. A 10-year-old *Acacia toritlis* browse yields about 4-6 kg dry leaf and 10-12 kg pods per year (Bekele, 2007). Fruits are preferred for stall-fed animals and should be ground to improve the efficiency of their utilization. Abdulrazak *et al.* (2000) reported CP content and DM digestibility of about 18% and 46%, respectively for *Acacia tortilis pods*.

Studies have indicated that application of various treatments and dilutions of browse leaves at different levels improved their palatability and intake (Alam *et al.* 2005; Bensalem *et al*. 2006).

Utilization of browses and shrubs for ruminants have been improved by reducing tannin levels through physical (Bensalem *et al.* 2005d; Vitti *et al.* 2005), chemical (Alam *et al.* 2005; Bensalem *et al.* 2005b; Wina *et al.* 2005) and biological treatments (Wambui *et al.* 2010). The most widely studied technique is the use of polyethylene glycol (PEG) which can bind tannin and reduce its negative effect (Makkar, 2003a; Bensalem *et al.* 2005c). Although PEG incorporation is quite effective, it is costly to be adopted by farmers. There is limited information on optimum inclusion levels of untreated or treated tree leaves to concentrate mixtures and their effects on utilization of poor quality roughages by goats. Thus, the objectives of this study were to examine the effects of supplementation of different proportions of concentrate, treated or untreated *Acacia toritlis* leaves on voluntary feed intake, digestibility, nutrient utilization and rumen fermentation characteristics of Arsi-Bale goats fed grass hay as a basal diet.

MATERIALS AND METHODS

Description of the study area

The study was conducted during February-May 2013 at the sheep farm of the School of Animal and Ranges Science of Hawassa University, Ethiopia, which is located at 7˚ 4´N latitude and 38˚ 3´E longitude, at an altitude of 1700 m above sea level. It receives a bi-modal rain fall of 1110 mm per annum. The mean, max and min. temperature of the study site are 13.1 ˚C and 27.6 ˚C for 2013, respectively (NMA, 2014).

Preparation of experimental diets

Rhodes grass (*Chloris gayana*) hay was chopped with manual chaff cutter to a length of about 4-6 cm to minimize wastage and selection. The leaves of *Acacia toritlis* were harvested for 7 consecutive days from mature plants in the Borana zone of Oromia National Regional State, southern Ethiopia. Leaves were hand harvested by pruning the lower branches and air-dried under shade for a week. Acacia leaves was treated with 3% (w/w) calcium hydroxide solution and air dried for a week before mixing with the concentrate mixture (Alam *et al.* 2005). A concentrate mixture was prepared from wheat bran (40%), maize grain (32%) and linseed cake (27%). Experimental diets were prepared out of concentrate mixture with different proportions of untreated or treated dried Acacia leaves. Common salt was added at the rate of 1% of the diet.

Experimental animals and management

Forty-eight yearling male Arsi-Bale goat breed weighing 13.8 ± 1.9 kg were purchased from Bulbulla market, about 90 km north of the experimental site (Hawassa University, Ethiopia). They were sprayed against external parasites with diazinon and dewormed with albendazole during quarantine period of 21 days. The animals were kept in individual pens equipped with individual feeding and watering troughs.

Experimental design and treatments

The experiment was conducted in a factorial design with two levels of Acacia leaf treatment with $Ca(OH)_2$ (untreated and treated) and by four levels of concentrate supplementation (25.50, 75 and 100%) to the basal diet Rhodes

grass hay. The treatment diets were: UL-0: hay + 300 g concentrate, UL-25: hay + 225 g concentrate and 75 g untreated dried leaves, UL-50: hay + 150 g concentrate and 150 g dried untreated leaves, UL-75: hay + 75 g concentrate and 225 g dried untreated leaves, UL-100: hay + 300 g dried untreated leaves, TL-0: hay + 300 g concentrate, TL-25: hay + 225 g concentrate and 75 g treated dried leaves, TL-50: hay + 150 g concentrate and 150 g dried treated leaves, TL-75: hay + 75 g concentrate and 225 g dried treated leaves and TL-100: hay + 300 g dried treated leaves. The Rhodes grass hay was offered in a separate feeding trough while mixtures of concentrate and Acacia leaf meals were offered together in individual feeding trough to each animal. At the end of quarantine and adaptation periods, the animals were weighed and blocked based on their initial body weight into three blocks of 16 animals.

Feeding trial

Goat nutrient requirements were estimated on the basis of NRC (1981) and diets were offered at the rate of 3% of body weight on DM basis for 84 days. The hay and supplements were delivered twice per day (08:00 and 14:00 h) in separate troughs. Rhodes grass hay was offered *ad libitum* at a refusal rate of 10%. Three hundred grams of supplements was offered to each animal in a separate trough. The refusals (hay and supplements) from individual pens were separately collected and weighed in the morning before daily offer. Daily intake was calculated as a difference between offers and refusals. Feed offered was sampled fortnightly but refusals were sampled daily and bulked for chemical analysis. Clean drinking water was provided free choice to each goat during the entire feeding period. Fortnightly live weight of individual goats was recorded in the morning before daily offer using a weighing scale during the entire experimental period.

Digestibility and metabolic trial

At the end of the feeding trial, four goats out of six were randomly selected from each treatment group and transferred to individual metabolic cages, which allow separate collection of feces and urine. The animals were allowed for 5 days of adaptation followed by a 7 days collection period. Goats were maintained on similar treatment diets of the feeding trial. Feces were collected by using fecal collection bags and urine was collected in bottles containing 10% (v/v) H_2SO_4. Total daily (24 h) feces and urine outputs were measured and after thorough mixing a 10% aliquot of each, was sampled daily. Feces, feed and refusals were oven dried at 60 ˚C for 48 h, milled to pass through 1 mm screen and stored in polythene bags. Parts of feces and urine samples were stored at -20 ˚C pending analysis. During the last three days, rumen liquor samples were taken from each animal using a stomach tube at 0, 2, 4, 6, 8 and 12 h after morning feed offer. The pH of the rumen liquor was immediately determined using an ionizable pH meter (Jenna instruments, Germany). Samples were strained through a clean double layer cheese cloth and sub-samples of 20 mL of the liquor fraction were taken, acidified with 2 mL of 10% H_2SO_4 (v/v) and stored at -20 ˚C for later NH_3-N analysis.

Chemical analysis

The dry matter (DM), ash, ether extract (EE) and kjeldahl nitrogen (N) analyses were performed in duplicate on dried samples (AOAC, 2005) and crude protein (CP) was calculated as N × 6.25. Neutral detergent fiber (NDF) was determined by the method of Van Soest *et al.* (1991) whereas acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest and Robertson (1985) using Ankom^{220} fiber analyzer (Ankom Technology®, Macedon, NY, USA). NDF was determined with sodium sulfite and without alpha amylase. Calcium was determined by complexometric titration method and phosphorous by spectrophotometer. Rumen liquor was analyzed for NH_3-N through steam distillation as described by Abdulrazak *et al.* (2000).

In vitro gas production was measured at 24 hrs of incubation for Rhodes grass hay, treated or untreated Acacia leaves and concentrate mixture by using rumen fluid obtained from adult sheep through suction tube. Strained rumen liquor and buffer solution were mixed in the ratio of 1:2 which was used for incubation feed samples in gas syringes at 39 ˚C. Metabolizable energy contents of experimental diets were estimated by the equation of:

$$ME\ (MJ/kg\ DM) = 2.2 + 0.136GP_{24} + 0.057CP$$

Where:
ME: metabolizable energy.
CP: crude protein of the diets.
GP_{24}: gas production at 24 hrs of incubation.

The phenolic composition of untreated and treated Acacia leaves were analyzed according to the standard procedure (Makkar, 2003b). The leaves were dried in hot air oven at 45 ˚C for 48 h. The samples were milled using Wiley laboratory mill (Thomson Wiley, USA) with 0.5 mm mesh size. Two hundred milligrams (200 mg) of ground leaves were extracted in a shaking water bath with 10 mL of 70% aqueous acetone solution (700 mL/L) (Makkar, 2003b). Total phenols (TP) and total tannins (TT) were determined by adding 0.25 mL Folin-Ciocalteau reagent (2N) and 1.25 mL sodium carbonate solution (200 g Na_2CO_3/L) to an aliquot of the supernatant and absorbance

was read at 725 nm in a spectrophotometer (Cary, USA). To determine TT, a binding tannin agent, insoluble polyvinyl polypyrrolidone (PVPP) was added to the extract. A calibration curve was prepared from aliquots of tannic acid solution (0.1 mg/mL; Merck GmbH, Darmstadt, Germany). The difference between TP and PVPP extract readings was an estimate of TT. The concentrations of TP and TT were calculated as tannic acid equivalents (eq) and expressed as g/kg DM. Condensed tannins (CT) were determined by using Butanol-HCl procedures and were expressed as leucocyanidin equivalent (% DM). The concentrations of condensed tannins were calculated by the formula:

(absorbance at 550 nm×78.26×dilution factor) / (% DM)

The dilution factor was equal to 1 if 10 mL of 70% acetone used and 0.5 mL per volume of the extract was taken (Porter *et al.* 1986; Makkar, 2003b).

Statistical analysis

Results of intake, digestibility, rumen parameters, NH_3-nitrogen, nitrogen and mineral balances were analyzed using the General Linear Model (GLM) procedure (SAS, 2000). Treatment means were separated using Tukey's HSD test.

RESULTS AND DISCUSSION

Chemical composition of the ingredients of experimental diets

The chemical composition of the ingredients of experimental diets is shown in Table 1. Rhodes grass hay used in this study as basal diet had higher contents of NDF, ADF and ADL and lower CP, EE, Ca and P as compared to Acacia leaves and the concentrate mixture. The CP and P contents of both untreated and calcium hydroxide treated Acacia leaves were comparable to the concentrate mixture but much higher than the grass hay.

The Ca content was highest in the treated leaves followed by the untreated leaves, concentrate mixture and the grass hay in a decreasing order. The EE content was highest in the concentrate mixture followed by the leaves whereas the lowest EE values were recorded in the grass hay. Untreated leaves had higher total tannin, hydrolysable tannin and condensed tannin contents as compared to leaves treated with 3% $Ca(OH)_2$.

When compared to Acacia leaves, concentrate mixture had higher contents of EE and P. Treated Acacia leaves had higher amount of NDF, ADF, ADL and Ca contents as compared to concentrate mixture. The CP, Ca and P contents of untreated and treated Acacia leaves were quite high which justify the possible feeding value of the leaves as protein and minerals supplement to feeds with lower level of N and minerals. Rhodes grass hay used in this experiment had high amount of NDF, ADF and ADL contents where as the CP of hay was slightly above 70 g kg^{-1} DM, a level indicated as minimal for optimal microbial growth and roughage intake (NRC, 1981).

The low CP and high fiber contents of hay in this experiment could be attributed to the maturity of the same hay during harvesting. Advances in maturity of plants were reported to be associated with the low CP and high cell wall contents of plant materials (McDonald *et al.* 2002). The CP content of hay in the current study was higher than those reported by other authors.

However, this result is in line with those reported in Kenya (Abdulrazak *et al.* 2005). This variability in nutrient content of hay could be caused by variation in site, season and stage of maturity of the hay harvested for the experiments. On the other hand, the high CP and relatively low fiber contents of *Acacia toritlis* leaf meal as compared to the Rhodes grass hay indicated the potential of this browse species to be used as supplement for poor quality roughages in ruminants' diets.

The average CP contents of both treated and untreated Acacia leaves (173 and 176 g/kg DM) were comparable to the values (178.8 g/kg DM) reported by Abebe (2010). It was slightly higher than those (156 g/kg DM) reported by Fadel Elseed *et al.* (2002).

Partial replacement of the acacia leaf in the concentrate diets was found to dilute the tannin contents without affecting other valuable nutrients. Partial replacement combined with treatment with $Ca(OH)_2$ reduced the tannin contents of the leaves in the diets from 17.2 to 5% condensed tannin (CT), the level recommended in the ruminant diets (Alam *et al.* 2005).

This is due to the dilution effect of the concentrate mixture and the deactivation of tannins by $Ca(OH)_2$ treatment. The NDF and ADF fractions of the leaves were higher than the values (217 and 154 g/kg DM) reported by Abebe (2010). This variability could be attributed to the differences in the site, season and stage of growth of the plant material during harvesting.

The mean CT contents of the leaves in this study was lower than the value (332 g/kg DM) reported by Abebe (2010) but higher than those of Fadel ELseed *et al.* (2002) in central Sudan.

The variability in CT contents could occur as a result of variability in stage of growth, season of harvesting and methods of processing for tannin determination (Bensalem *et al.* 2006). The decrease in tannin contents of treated leaves by $Ca(OH)_2$ may be due to high pH values of $Ca(OH)_2$, which easily oxidize tannins in the leaves to quinines and further promote covalent bond formation with other compounds (Vitti *et al.* 2005).

Table 1 Chemical composition of ingredients of experimental diets (g/kg DM)

Chemical components	Ingredients of experimental diets			
	Hay	Untreated Acacia leaves	$Ca(OH)_2$ treated Acacia leaves	Concentrate mixture
Dry matter	909	907	905	905
Ash	80	71	76	72
Crude protein	78	173	176	171
Ether extract	10	44	28	58
Neutral detergent fiber	462	342	360	341
Acid detergent fiber	350	176	206	111
Acid detergent lignin	190	57	71	13
Calcium	6	15	23	9
Phosphorous	1	6	6	7
Total phenol	ND	265	42	ND
Total tannin	ND	252	76	ND
Non tannin phenol	ND	76	74	ND
Hydrolysable tannin	ND	85	83	ND
Condensed tannin	ND	172	33	ND
Metabolizable energy (MJ/kg DM)	6.8	11.6	11.7	12.1

ND: not determined.

Such complex compounds are insoluble detergent solutions and increased the NDF, ADF and ADL contents of treated Acacia leaves (Terrill *et al.* 1992; Vitti *et al.* 2005). Alkali treatment might also promote artifact formation of treated leaves that could reduce the solubility of the leaves in the detergent solution. The alkalinity of calcium hydroxide solution treatment was considered as the main reason for reduction of extractable tannins in the treated leaves by oxidation of tannins into quinines, leading to destruction of reactive hydroxyl groups of tannins in the leaves (Bensalem *et al.* 2005a).

Feed intake and nutrient digestibility of experimental diets

The dietary intakes of goats fed on experimental diets are given in Table 3. The DM intake (DMI) of the basal hay was similar (P>0.05) across the treatments. But increasing trend of DMI was observed as the level of Acacia leaf meal (ALM) increased in the concentrate mixture of both untreated and treated leaf meal groups.

Dry matter intake of the supplement was significantly higher in goats fed UL-50 than those fed UL-100, TL-25 and TL-100. The DMI for the rest of treatments were intermediate. Intakes of OM and NDF were similar among the treatment diets. However, increasing trends were observed as the level of treated ALM supplement increased as opposed to untreated ALM supplementation. CP intake was significantly (P<0.05) higher in UL-50, TL-50, TL-75 and TL-100 as compared to UL-100. But the other diets had intermediate CP intake values. ADF intake was significantly higher in UL-100, TL-50 and TL-100 as compared to other diets. The rest of the experimental diets had comparable ADF intake values.

ADL intake was significantly (P<0.05) lower in goats fed control diet than TL-25 which in turn lower than UL-50, TL-50, UL-100 and TL-100 in the same order. In the current study, all experimental goats readily accepted both untreated and treated Acacia leaf meals offered to them. The amount of leaf DM consumed by UL-50 and TL-75 groups were higher than the other treatment groups indicating that the CT concentration above this replacement level could be one of the important causes for reduced intake of the diets. The CP intake was higher (P<0.05) for treated Acacia leaf supplemented group at 75% replacement, followed by 50% replacement of untreated leaf meal. This shows the positive effect of both treatment and partial replacement on intake of Acacia leaf meal. Similar trend was observed for total dry matter intake in g/kg $BW^{0.75}$ per day. Intakes of goats for DM, OM, CP and NDF from Rhodes grass hay were slightly higher in TL-100 which was a compensation for slightly lower nutrient intakes from the experimental diet at the same level of replacement. Thus, both alkali treatment and leaf meal supplementation had improved CP intake of the experimental goats complementarily. This might be due to higher CP contents of Acacia leaves and reduction of the astringent effect of CT by alkali treatment which might have increased the intake in the treated leaf meal groups. Acacia leaf meal and other legume browse supplementation were found to improve the CP intake of goats when anti-nutrient effect of CT was removed (Abdulrazak *et al.* 2005; Toplu *et al.* 2013). The effect of $Ca(OH)_2$ treatment on *Acacia nilotica* pods was observed to decrease the tannin contents and increased the DMI, OMI and CPI as compared to untreated pods for dairy cattle (Barman and Rai, 2008) and dairy goats (Bayssa, 2006).

Table 2 Chemical composition of experimental diets (% DM)

Parameters	$Ca(OH)_2$ treatment	Level of leaf replacement in concentrate mix (%)					Mean±SE
		0	25	50	75	100	
DM (%)	UL	90.5	89.5	92.2	89.8	90.7	**90.5±0.38**
	TL	90.5	90.3	90.2	90.4	90.5	**90.4±0.17**
Ash	UL	7.2	6.2	6.0	6.1	7.1	**6.4±0.20**
	TL	7.2	6.3	6.2	7.0	7.6	**6.8±0.16**
Ether extract	UL	5.8^{a}	5.0^{ab}	4.2^{ab}	3.7^{b}	4.4^{abA}	**4.9±0.24**
	TL	5.8^{a}	4.8^{ab}	3.9^{b}	3.9^{b}	2.8^{bB}	**4.24±0.30**
CP	UL	17.1	17.0	16.9	16.0	17.3	**16.9±0.32**
	TL	17.1	16.7	17.4	17.3	17.6	**17.2±0.32**
NDF	UL	34.1	34.2	35.9	37.6	38.1	**36.0±0.83**
	TL	34.1	36.0	35.6	39.4	40.0	**37.0±0.91**
ADF	UL	11.2^{b}	12.2^{b}	12.6^{b}	13.2^{b}	17.5^{aB}	**13.3±0.54**
	TL	11.2^{b}	10.8^{b}	13.0^{b}	13.7^{b}	20.6^{aA}	**13.8±0.84**
ADL	UL	1.3^{b}	1.5^{b}	2.2^{b}	2.7^{b}	5.7^{aB}	**2.7±0.41**
	TL	1.3^{b}	1.6^{b}	2.5^{ab}	3.9^{ab}	7.2aA	**3.2±0.53**
Hemicellulose	UL	23.0^{a}	21.4^{ab}	20.0^{ab}	18.5^{bB}	16.7^{bB}	**22.7±0.98**
	TL	22.4^{b}	22.6^{b}	23.4^{b}	25.8^{abA}	29.1^{aA}	**23.2±1.22**
Cellulose	UL	9.8	10.5	10.7	10.4	11.9	**10.7±0.30**
	TL	9.8	9.8	10.2	10.6	13.5	**10.7±0.42**
Metabolizable energy (MJ/kg DM)	UL	12.1	11.4	12.3	12.1	11.6	**11.9±0.19**
	TL	12.1	11.8	10.9	12.5	11.6	**11.8±0.19**

DM: dry matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre and ADL: acid detergent lignin.
$^{a, b, c, d}$: the means within the same row with different letter, are significantly different (P<0.05).
$^{A, B}$: the means within the same column with different letter, are significantly different (P<0.05).
SE: standard error.
UL-0: hay + 300 g concentrate; UL-25: hay + 225 g concentrate and 75 g untreated dried leaves; UL-50: hay + 150 g concentrate and 150 g untreated dried leaves; UL-75: hay + 75 g concentrate and 225 g untreated dried leaves; UL-100: hay + 300 g untreated dried leaves; TL-0: hay + 300 g concentrate; TL-25: hay + 225 g concentrate and 75 g dried treated leaves; TL-50: hay + 150 g concentrate and 150 g treated dried leaves; TL-75: hay + 75 g concentrate and 225 g treated dried leaves and TL-100: hay + 300 g treated dried leaves.

Table 3 Feed intake (g/head/d) of goats fed basal diet of Rhodes grass hay supplemented by different proportions of concentrate mixture and untreated or calcium hydroxide treated *Acacia toritilis* leaves

Parameters	$Ca(OH)_2$ treatment	Level of leaf replacement in concentrate mix (%)					Mean±SE
		0	25	50	75	100	
Dry matter (g/head/day)							
Hay	UL	275	293.4	296.6	307.6	295.3	**298.2±13.3**
	TL	275	268.1	311.2	263.2	305.8	**287.1±13.4**
	Mean±SE	**275±13.5**	**280.8±16.4**	**303.9±16.0**	**285.4±16.7**	**300.5±21.7**	
Supplement	UL	260^{ab}	258.2^{ab}	263.9^{aA}	254.3^{ab}	239.6^{b}	**254.0±4.3**
	TL	260^{ab}	237.5^{b}	258.8^{abB}	257.2^{ab}	238.8^{b}	**248.1±4.1**
	Mean±SE	**260±1.1**	**247.8±6.7**	**261.4±3.1**	**255.8±3.8**	**239.2±6.9**	
Total	UL	522	551.6	560.5	561.9	534.9	**552.2±13.1**
	TL	522	505.6	570.0	520.4	544.6	**535.2±15.2**
	Mean±SE	**522±4.0**	**528.6±18.3**	**565.2±16.6**	**541.2±19.8**	**539.8±25.5**	
Intake of other components (g/head/day)							
OM	UL	481	495	506	493	492	**451.9±10.7**
	TL	481	478	532	509	533	**432.3±10.0**
	Mean±SE	**481±2.9**	**431.5±15.3**	**459.5±14.2**	**447.1±15.7**	**436.5±12.0**	
CP	UL	65.9^{ab}	65.6^{ab}	71.0^{a}	65.6^{abB}	60.7^{bB}	**65.9±1.3**
	TL	65.9^{ab}	67.1^{ab}	72.3^{a}	70.0^{aA}	72.1^{aA}	**65.2±1.5**
	Mean±SE	**65.9±3.7**	**63.9±1.8**	**68.5±1.4**	**64.9±1.7**	**65.1±2.5**	
NDF	UL	220	227.4	235.7	222.0	220.1	**226.3±5.5**
	TL	220	215.0	237.4	249.8	232.2	**233.6±7.4**
	Mean±SE	**320±1.85**	**221.2±9.3**	**236.6±7.2**	**235.9±9.6**	**226.2±117**	
ADF	UL	123^{b}	132^{b}	133^{abB}	130^{b}	144^{aB}	**134.6±3.2**
	TL	123^{b}	122^{b}	146^{abA}	138^{ab}	165^{aA}	**142.3±4.7**
	Mean±SE	**123±1.06**	**126.7±4.0**	**138.5±4.7**	**134.0±5.2**	**154.7±6.0**	
ADL	UL	31.0^{b}	60.0^{a}	58.3^{aB}	58.7^{aB}	68.7aB	**61.4±1.8**
	TL	31.0^{d}	53.7^{c}	66.5^{bA}	65.7^{bA}	79.6^{aA}	**66.4±2.6**
	Mean±SE	**31.0±0.78**	**56.9±2.2**	**62.4±2.6**	**62.2±2.8**	**74.2±3.1**	

DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre and ADL: acid detergent lignin.
$^{a, b, c, d}$: the means within the same row with different letter, are significantly different (P<0.05).
$^{A, B}$: the means within the same column with different letter, are significantly different (P<0.05).
SE: standard error.
UL-0: hay + 300 g concentrate; UL-25: hay + 225 g concentrate and 75 g untreated dried leaves; UL-50: hay + 150 g concentrate and 150 g untreated dried leaves; UL-75: hay + 75 g concentrate and 225 g untreated dried leaves; UL-100: hay + 300 g untreated dried leaves; TL-0: hay + 300 g concentrate; TL-25: hay + 225 g concentrate and 75 g dried treated leaves; TL-50: hay + 150 g concentrate and 150 g treated dried leaves; TL-75: hay + 75 g concentrate and 225 g treated dried leaves and TL-100: hay + 300 g treated dried leaves.

In contrast to the present study, Alam *et al.* (2005) reported that treatment of *Albezia procera* leaves foliage by 3% (w/w) $Ca(OH)_2$ reduced the extractable tannin concentration by 92% without improvement of the intake of young goats fed on basal hay diet supplemented with wheat bran and fresh treated leaves as compared to combined effect of PEG and $Ca(OH)_2$ treatment. This could be probably due to differences in browse species in relation to the tannin concentration and biochemical structures of the phenolic compounds in the browse plants. The variability in the methods of processing of the browse leaves before feeding and the composition of replacement diets offered to the goats might have additional contribution to the differences between the trials. However, Barman and Rai (2008) reported the superior effect of $Ca(OH)_2$ treatment alone as compared to the combined effects of both $Ca(OH)_2$ and PEG treatments of Acacia pods at different level of combinations on nutrient intake, digestibility, weight changes and milk yield in dairy goats and dairy cattle, respectively.

Dry matter and nutrient digestibility of the experimental diets are given in Table 4. Percentages of DM, CP, and NDF digestibility were positively ($P>0.05$) affected by the experimental diets. Dry matter digestibility was significantly higher ($P<0.05$) in UL-25, UL-50, UL-75 and TL-75 as compared to UL-100 and TL-100 treatments and other treatments had intermediate values. Crude protein digestibility was significantly ($P<0.05$) higher in UL-0, UL-25 and TL-75 than in UL-50, UL-100, TL-25 and TL-100.

Digestibility of NDF was significantly higher in UL-0 than UL-100 and both TL-0 and TL-75 were higher than TL-25 and TL-50. At 75 % level of supplementation TL-75 was higher than UL-75 and TL-100 was higher than UL-100 leaf supplements.The result of current study agree with those of Bensalem *et al.* (2005d) which reported improvement in CP and NDF digestibility of wood ash treated *Acacia cyanophyla* leaves fed to Barbane goats without having negative effects on the DM and OM intake and digestibility.

In this feeding trial, no observable physiological disturbances, health problems and deaths of the experimental animals were recorded as a result of the experimental diets. This could possibly indicate prior adaptation of the goats to Acacia leaf with high CT concentration in their natural habitat.

Anti-nutritional factors such as CT inhibit plant protein degradation and decrease sulphur availability in the rumen, which in turn affect the digestibility of total tract nitrogen and plant cell walls (Amita, 2014).

The presence of active CT in the former diets may be attributed to the reduction in nutrient digestibility of the diets, but in the remaining diets it was clearly observed that leaf meal replacement increased the digestibility of the diets, due to the fact that the effect CT in the diets was reduced to the level which might have little or no effect on the digestibility of the nutrients. This result is in line with the report of earlier studies (Bensalem *et al.* 2005d; Wina *et al.* 2005).

Barry (1987) indicated that 2-3% CT in ruminant diets had beneficial advantages, as it reduces the degradation of useful protein in the rumen by the formation of protein-tannin complexes.

However, at higher level of concentration (more than 6% DM), CT in supplements was reported to reduce intake, digestibility and absorption of nutrients from gastro intestinal tract (Njidda and Ikhimioya, 2013).

Increase in nutrient digestibility at the lower level of leaf replacement in untreated leaf supplements (UL-0 and UL-25) and the decrease at the higher level of leaf replacement, could be due to the concentration of tannins in the respective levels of supplemental ALM, which might have hindered the nutrient digestibility of the experimental goats. In case of treated Acacia leaf meal groups, nutrient digestibility was not affected by the level of leaf replacement in the concentrate mixtures from the lower to the higher level of replacement.

This could show the tannin deactivation effect of calcium hydroxide in the Acacia leaves, so that the digestibility of the nutrient in the supplement had been improved. Similar observations were reported by other authors (Alam *et al.* 2005).

Nitrogen and mineral balances in Arsi-Bale goats

Nitrogen balances of the experimental diets fed to Arsi-Bale goats are shown in Table 5. Nitrogen intake from basal hay, fecal nitrogen excretion and total nitrogen excretion were not affected by the experimental diets. On the other hand, nitrogen intake from supplements, total nitrogen intake, urinary nitrogen excretion and nitrogen retention were significantly ($P<0.05$) affected by the experimental diets.

Nitrogen intake of supplements was higher ($P<0.05$) in UL-50 and TL-75 than in UL-50 and TL-25 diets and in the rest, it was similar. Total nitrogen intake was higher ($P<0.05$) in TL-100 than in TL-25. The nitrogen intakes from the rest of the diets were similar. Nitrogen intakes from the basal diet were similar across the treatments. Nitrogen intake from experimental diets in both treated and untreated ALM at 50% supplement level was higher as compared to the remaining diets.

A decreasing trend was observed in the nitrogen intake with increasing level of untreated ALM whereas an increasing trend was observed for treated ALM diets. This could probably be due to higher CT contents of untreated ALM and vice versa in treated ALM (Amita 2014; Olafadehan *et al.* 2014).

Table 4 Nutrient digestibility (%) of goats fed on a basal diet of Rhodes grass hay supplemented by different proportion of concentrate mixture and untreated or calcium hydroxide treated *Acacia toritilis* leaves

Parameters	$Ca(OH)_2$ treatment	Level of leaf replacement in concentrate mix (%)					Mean±SE
		0	25	50	75	100	
DM	UL	67.3^{ab}	72.6^{a}	72.2^{a}	71.8^{a}	64.1^{b}	**67.4±1.5**
	TL	67.3^{ab}	66.4^{ab}	68.4^{b}	73.0^{a}	63.0^{b}	**65.2±1.4**
	Mean±SE	**67.3±2.7**	**65.6±2.4**	**67.0±2.0**	**70.5±1.0**	**62.0±1.7**	
OM	UL	75	71.5	68.4^{B}	65.4^{B}	62.3^{B}	**74.0±1.4**
	TL	75	73.6	76.9^{A}	77.8^{A}	74.8^{A}	**71.2±1.7**
	Mean±SE	**75±1.8**	**72.6±2.4**	**72.7±2.2**	**76.6±1.4**	**68.6±2.3**	
CP	UL	82	83.6	79.0	73.4^{B}	73.6	**77.5±1.9**
	TL	82^{ab}	80.8^{b}	78.0^{b}	85.4^{aA}	77.1^{b}	**74.5±2.9**
	Mean±SE	**82±1.6**	**80.1±2.0**	**70.0±3.2**	**77.2±2.3**	**71.3±5.2**	
NDF	UL	72^{a}	68.1^{a}	67.0^{a}	62.7^{bB}	50.2^{cB}	**66.7±1.9**
	TL	72^{a}	65.1^{b}	66.3^{b}	74.4^{aA}	61.2^{bA}	**66.7±1.7**
	Mean±SE	**72±2.0**	**66.6±2.7**	**66.6±2.6**	**70.6±2.2**	**63.1±2.1**	

DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fibre and ADF: acid detergent fibre.
[a, b, c, d]: the means within the same row with different letter, are significantly different (P<0.05).
[A, B]: the means within the same column with different letter, are significantly different (P<0.05).
SE: standard error.
UL-0: hay + 300 g concentrate; UL-25: hay + 225 g concentrate and 75 g untreated dried leaves; UL-50: hay + 150 g concentrate and 150 g untreated dried leaves; UL-75: hay + 75 g concentrate and 225 g untreated dried leaves; UL-100: hay + 300 g untreated dried leaves; TL-0: hay + 300 g concentrate; TL-25: hay + 225 g concentrate and 75 g dried treated leaves; TL-50: hay + 150 g concentrate and 150 g treated dried leaves; TL-75: hay + 75 g concentrate and 225 g treated dried leaves and TL-100: hay + 300 g treated dried leaves.

Table 5 Balances of nitrogen (g/day) in goats fed on a basal diet of Rhodes grass hay supplemented by different proportion of concentrate mixture and untreated or calcium hydroxide treated *Acacia toritilis* leaves

Parameters	$Ca(OH)_2$ treatment	Level of leaf replacement in concentrate mix (%)					Mean±SE
		0	25	50	75	100	
Nitrogen intake (g/head/day)							
Hay	UL	3.4	3.7	3.7	3.8	3.7	**3.7±0.14**
	TL	3.4	3.4	3.9	3.3	3.8	**3.6±0.17**
	Mean±SE	**3.4±0.2**	**3.5±0.2**	**3.8±0.2**	**3.6±0.2**	**3.8±0.3**	
Supplement	UL	7.1^{a}	7.0^{a}	7.2^{a}	6.5^{b}	6.6^{b}	**6.8±0.10**
	TL	7.1^{a}	6.4^{b}	7.2^{a}	7.1^{a}	6.7^{b}	**6.8±0.10**
	Mean±SE	**7.1±0.1**	**6.7±0.2**	**7.2±0.1**	**6.8±0.2**	**6.7±0.2**	
Total	UL	10.5	10.7	10.9	10.3	10.3	**10.5±0.20**
	TL	10.5^{ab}	9.8^{b}	11.1^{a}	10.4^{ab}	10.5^{ab}	**10.4±0.20**
	Mean±SE	**10.5±0.1**	**10.2±0.3**	**11.0±0.2**	**10.4±0.3**	**10.4±0.4**	
N excretion and retention (g/head/day)							
Fecal N	UL	1.6	1.6	3.0	2.2	2.5	**2.1±0.20**
	TL	1.6	2.2	2.7	1.5	2.4	**2.2±0.20**
	Mean±SE	**1.6±0.2**	**1.8±0.3**	**2.3±0.3**	**1.8±0.2**	**2.5±0.4**	
Urinary N	UL	1.4	1.9	1.6	1.5	1.0	**1.4±0.14**
	TL	1.4	1.8	1.3	1.4	1.0	**1.4±0.16**
	Mean±SE	**1.4±0.1**	**1.8±0.3**	**1.4±0.2**	**1.4±0.1**	**1.0±0.6**	
Total N excretion	UL	3.0	3.4	3.6	3.7	3.5	**3.5±0.20**
	TL	3.0	4.0	4.0	2.9	3.4	**3.5±0.30**
	Mean±SE	**3.0±0.2**	**3.7±0.3**	**3.8±0.4**	**3.3±0.3**	**3.4±0.3**	
N retention	UL	7.5^{a}	7.3^{aA}	7.3^{a}	6.6^{bB}	6.8^{b}	**7.1±0.40**
	TL	7.5^{a}	5.8^{bB}	7.1^{ab}	7.5^{aA}	7.1^{ab}	**7.1±0.30**
	Mean±SE	**7.5±0.4**	**6.5±0.4**	**7.2±0.4**	**7.1±0.3**	**7.0±0.5**	

[a, b, c, d]: the means within the same row with different letter, are significantly different (P<0.05).
[A, B]: the means within the same column with different letter, are significantly different (P<0.05).
SE: standard error.
UL-0: hay + 300 g concentrate; UL-25: hay + 225 g concentrate and 75 g untreated dried leaves; UL-50: hay + 150 g concentrate and 150 g untreated dried leaves; UL-75: hay + 75 g concentrate and 225 g untreated dried leaves; UL-100: hay + 300 g untreated dried leaves; TL-0: hay + 300 g concentrate; TL-25: hay + 225 g concentrate and 75 g dried treated leaves; TL-50: hay + 150 g concentrate and 150 g treated dried leaves; TL-75: hay + 75 g concentrate and 225 g treated dried leaves and TL-100: hay + 300 g treated dried leaves.

Urinary nitrogen excretion was lower (P<0.05) in UL-100 than in UL-25 but the remaining diets had similar values. Nitrogen retention was higher (P<0.05) in UL-25 and TL-50 than TL-25. But the rest of the diets gave comparable nitrogen retention.

Decreasing nitrogen retention was observed as the level of leaf replacement increased in the untreated ALM diets (UL-25 to UL-100) but the reverse was treated ALM diets (TL-25 to TL-100). Calcium hydroxide treatment of the diets improved nitrogen retention by reducing fecal and

total nitrogen excretion from goats. This might be due to the polymerization of tannin with calcium ions so that dietary nitrogen is available both for ruminal microbes for protein synthesis and also for lower tract digestion for efficient absorption. Untreated leaf meal groups excreted higher (P<0.05) fecal nitrogen and thus lower nitrogen retention in these groups. This observation is in agreement with the findings of (Olafadehan *et al.* 2014). On the other hand, Alam *et al.* (2005) reported reduction in nitrogen retention and an increase in fecal and urinary nitrogen in feeding young goats with 3% $Ca(OH)_2$ treated *Albezia procera* fresh leaf meals, with basal hay diets supplemented by wheat bran. The differences might have been caused by variability between the browse spp. in their tannin contents and structures, methods of processing before feeding and the type of supplements used in the experimental diets.

In this experiment, urinary nitrogen excretion was observed to be higher in diets supplemented with treated than untreated ALM diets. This could be probably as a result of availability of excess amount feed nitrogen in the rumen for fermentation, as compared to available energy supplement in the diets as the level of the replacement increased in the treatments. The limited energy supply to the rumen ecosystem can contribute to the spill off nitrogen in the form of urinary nitrogen, as a result of restricted capacity of the microbes for protein synthesis. A reduced urinary nitrogen excretion in sole untreated Acacia meal diets might also be a mechanism by which animals compensated for the higher fecal N excretion with increased tannin level in the diets. This is why the N balances of the experimental diets were observed to be positive in contrast to negative N balance in different experiments. Both $Ca(OH)_2$ treatment and partial substitution of leaf meal had synergistic effect on nitrogen intake, retention and partitions of nitrogen excretion in this experiment.

Calcium and Phosphorous balances of the experimental diets fed to *Arsi-Bale* goats are shown in Tables 6 and 7. Intakes of Ca and P from basal hay, excretion of fecal Ca and P and also total Ca and P intakes were not affected (P>0.05) by the experimental diets. However, Ca intake from leaf supplement was higher in TL-100 and lower in UL-25 diet.

The remaining diets had similar Ca concentrations. Similar trends were observed for total Ca intake among the experimental groups. Phosphorous intake from supplemental diets were significantly higher (P<0.05) for UL-75, TL-25, TL-50 and TL-75 than the rest of the diets. However, intermediate values were observed for UL-100 and TL-100. No significant differences (P>0.05) were observed between UL-25 and UL50 diets. Total P intake of the goats followed the same trend as intake from the leaf supplements. Intake of Ca from basal hay, excretion of fecal Ca and total Ca intake were not affected (P>0.05) by the experimental diets. Whereas, Ca intake from leaf supplement was higher in TL-100 than in UL-25 diet. The intakes of rest of the diets were similar. The urinary Ca excretion was higher in TL-75 and TL-100 than in UL-25, UL-50, UL-75 and UL-100 diets. The rest of the diets had intermediate Ca excretion. Ca retention was higher (P<0.05) in TL-100 than in UL-75. The other experimental diets had similar Ca retention.

This might be due to $Ca(OH)_2$ treatment which could have contributed to the rise in the calcium in the diets of treated groups. In addition, *Acacia totilis* leaves had relatively higher calcium content as compared the concentrate mixture (Vitti *et al.* 2005; Ondiek *et al.* 2005), although the availability of Ca might be affected by the fiber content of the diets.

Total calcium intakes in hay basal diets were significantly different across the treatments. The calcium retention was higher in T8 than untreated Acacia leaves across the treatments. Total Ca excretion was similar among treatments. However, increasing trends of total excretion of Ca was observed in treated ALM supplement, followed by 75% untreated ALM supplements. Fecal Ca excretion was also not significantly (P<0.05) different among treatments, even though higher fecal calcium contents was observed in untreated 75% ALM followed by treated 100% ALM supplement. This was possibly due to an increasing trend of total calcium intake in the treated ALM diets. Urinary Ca excretion was higher in treated ALM groups than in untreated ALM supplements.

The highest Ca excretion was observed in TL-100 followed by TL-50 and TL-75.Whereas, the lowest urinary Ca excretion was in UL-100 and UL-50 diets. This was due to deactivation effect of $Ca(OH)_2$ treatment on CT contents of the acacia leaves which resulted in increased bioavailability of Ca from experimental diets both in the rumen and lower tract for absorption. However, there was increasing trend of Ca excretion in feces for untreated ALM groups. Calcium retention was higher in TL-100 than TL-75 and UL-25 diets. The lowest value was in UL-75. This could be attributed to the effect of calcium hydroxide treatment combined with higher level of Ca content in the leaves of *Acacia toritlis*.

Intakes of P from basal hay, excretion of fecal P and total P intakes were not affected (P>0.05) by the experimental diets. Phosphorous intake from supplemental diets was higher (P<0.05) in UL-50, TL-25, TL-50 and TL-75 than the rest of the diets. However, intermediate P intakes were observed for UL-100 and TL-100. No significant differences (P>0.05) were observed between UL-25 and UL-50 diets.

Table 6 Balance of calcium (g/day) in goats fed on a basal diet of Rhodes grass hay supplemented by different proportion of concentrate mixture and untreated or calcium hydroxide treated *Acacia toritilis* leaves

Parameters	$Ca(OH)_2$ treatment	Level of leaf replacement in concentrate mix (%)					Mean±SE
		0	25	50	75	100	
Calcium intake (g/head/day)							
Hay	UL	1.6	1.7	1.7	1.8	1.7	**1.7±0.07**
	TL	1.6	1.6	1.8	1.5	1.8	**1.7±0.08**
	Mean±SE	**1.6±0.02**	**1.7±0.04**	**1.8±0.03**	**1.7±0.01**	**1.8±0.03**	
Supplement	UL	1.9^{c}	2.0^{cB}	3.1^{bB}	2.5^{bcB}	3.4^{aB}	**2.8±0.15**
	TL	1.9^{c}	2.9^{bcA}	3.4^{bA}	3.9^{Ba}	5.0^{aA}	**3.8±0.20**
	Mean±SE	**1.9±0.02**	**2.5±0.03**	**3.3±0.05**	**3.2±0.02**	**4.2±0.02**	
Total intake	UL	3.5^{c}	3.7^{c}	4.8^{b}	4.3^{bc}	5.2^{aB}	**5.0±0.16**
	TL	3.5^{c}	4.5^{bc}	5.2^{b}	5.4^{b}	6.8^{aA}	**5.5±0.24**
	Mean±SE	**3.5±0.02**	**4.1±0.03**	**5.0±0.01**	**4.9±0.04**	**6.0±0.02**	
Ca excretion and retention (g/head/day)							
Fecal Ca	UL	1.6	1.7	1.7	2.4	2.2	**2.0±0.24**
	TL	1.6	1.5	2.1	1.1	2.2	**1.7±0.21**
	Mean±SE	**1.6±0.04**	**1.6±0.07**	**1.9±0.09**	**1.8±0.04**	**2.2±0.01**	
Urinary Ca	UL	0.2^{a}	0.2^{aB}	0.2^{aB}	0.2^{aB}	0.1^{bB}	**0.16±0.04**
	TL	0.2^{d}	0.3^{cA}	0.4^{bA}	0.5^{aA}	0.5^{aA}	**0.44±0.03**
	Mean±SE	**0.2±0.01**	**0.3±0.01**	**0.3±0.05**	**0.3±0.08**	**0.3±0.04**	
Total Ca excretion	UL	1.8	1.9	1.9	2.6	2.3	**2.16±0.24**
	TL	1.8	1.8	2.5	1.6	2.7	**2.19±0.21**
	Mean±SE	**1.8±0.03**	**1.8±0.05**	**2.2±0.03**	**2.1±0.08**	**2.5±0.07**	
Ca retention	UL	1.8^{b}	1.9^{b}	3.0^{a}	1.7^{bB}	2.8^{aB}	**2.34±0.26**
	TL	1.8^{c}	2.7^{b}	2.6^{b}	3.8^{aA}	4.0^{aA}	**3.26±0.24**
	Mean±SE	**1.8±0.05**	**2.3±0.07**	**2.8±0.07**	**2.8±0.09**	**3.4±0.05**	

$^{a, b, c, d}$: the means within the same row with different letter, are significantly different (P<0.05).
$^{A, B}$: the means within the same column with different letter, are significantly different (P<0.05).
SE: standard error.
UL-0: hay + 300 g concentrate; UL-25: hay + 225 g concentrate and 75 g untreated dried leaves; UL-50: hay + 150 g concentrate and 150 g untreated dried leaves; UL-75: hay + 75 g concentrate and 225 g untreated dried leaves; UL-100: hay + 300 g untreated dried leaves; TL-0: hay + 300 g concentrate; TL-25: hay + 225 g concentrate and 75 g dried treated leaves; TL-50: hay + 150 g concentrate and 150 g treated dried leaves; TL-75: hay + 75 g concentrate and 225 g treated dried leaves and TL-100: hay + 300 g treated dried leaves.

Table 7 Balance of Phosphorous (g/day) in goats fed on a basal diet of Rhodes grass hay supplemented by different proportion of concentrate mixture and untreated or calcium hydroxide treated *Acacia toritilis* leaves

Parameters	$Ca(OH)_2$ treatment	Level of leaf replacement in concentrate mix (%)					Mean±SE
		0	25	50	75	100	
P intake (g/head/day)							
Hay	UL	0.3	0.4	0.4	0.4	0.4	**0.37±0.014**
	TL	0.3	0.3	0.4	0.3	0.4	**0.35±0.017**
	Mean±SE	**0.3±0.01**	**0.4±0.02**	**0.4±0.04**	**0.4±0.05**	**0.4±0.03**	
Supplement	UL	1.6^{a}	1.0^{c}	1.0^{cB}	1.2^{bB}	1.4^{a}	**1.16±0.039**
	TL	1.6^{a}	1.1^{b}	1.3^{aA}	1.3^{aA}	1.3^{a}	**1.26±0.023**
	Mean±SE	**1.6±0.05**	**1.1±0.06**	**1.2±0.03**	**1.3±0.07**	**1.4±0.09**	
Total intake	UL	1.9^{a}	1.4^{c}	1.4^{cB}	1.6^{b}	1.7^{a}	**1.53±0.034**
	TL	1.9^{a}	1.5^{b}	1.7^{aA}	1.6^{b}	1.7^{a}	**1.61±0.043**
	Mean±SE	**1.9±0.07**	**1.5±0.06**	**1.6±0.08**	**1.6±0.07**	**1.7±0.09**	
P excretion and retention (g/head/day)							
Fecal P	UL	1.0	1.0	0.9	0.9	0.9	**1.61±0.068**
	TL	1.0	1.0	1.3	1.0	1.3	**1.13±0.088**
	Mean±SE	**1.0±0.01**	**1.0±0.02**	**1.1±0.01**	**1.0±0.03**	**1.1±0.05**	
Urinary P	UL	0.2^{b}	0.1^{b}	0.2^{b}	0.3^{ab}	0.4^{aA}	**0.25±0.030**
	TL	0.2	0.1	0.1	0.1	0.1^{B}	**0.08±0.010**
	Mean±SE	**0.2±0.07**	**0.1±0.07**	**0.2±0.06**	**0.2±0.03**	**0.3±0.01**	
Total P excretion	UL	1.2	1.2	1.1	1.1	1.3	**1.18±0.056**
	TL	1.2	1.1	1.4	1.1	1.4	**1.21±0.087**
	Mean±SE	**1.2±0.08**	**1.2±0.09**	**1.3±0.07**	**1.1±0.09**	**1.4±0.01**	
P retention	UL	0.8^{a}	0.2^{bB}	0.3^{b}	0.5^{a}	0.5^{aA}	**0.35±0.06**
	TL	0.8^{a}	0.4^{aA}	0.3^{b}	0.6^{a}	0.3^{bB}	**0.40±0.08**
	Mean±SE	**0.8±0.01**	**0.3±0.02**	**0.3±0.05**	**0.6±0.07**	**0.4±0.04**	

$^{a, b, c, d}$: the means within the same row with different letter, are significantly different (P<0.05).
$^{A, B}$: the means within the same column with different letter, are significantly different (P<0.05).
SE: standard error.
UL-0: hay + 300 g concentrate; UL-25: hay + 225 g concentrate and 75 g untreated dried leaves; UL-50: hay + 150 g concentrate and 150 g untreated dried leaves; UL-75: hay + 75 g concentrate and 225 g untreated dried leaves; UL-100: hay + 300 g untreated dried leaves; TL-0: hay + 300 g concentrate; TL-25: hay + 225 g concentrate and 75 g dried treated leaves; TL-50: hay + 150 g concentrate and 150 g treated dried leaves; TL-75: hay + 75 g concentrate and 225 g treated dried leaves and TL-100: hay + 300 g treated dried leaves.

Total P intake of the goats followed the same trend as intake from the ALM supplements. However, P excretion was higher (P<0.05) in UL-100 than other diets.

Phosphorous retention was higher (P<0.05) in UL-75, UL-100 and TL-75 than the other experimental diets. This might be due to $Ca(OH)_2$ treatment which could have contributed to rise in the calcium in the diets of treated groups. But the reduced availability of P might be due to high fiber content of the diets of acacia leaves in UL-100 diet.

Total phosphorous intake in hay basal diets was significantly different across the treatments. Phosphorous retention was observed to be slightly higher in TL-100 (treated leaves) group than non treated Acacia leaves across the treatments. Total P excretions were not affected by treatments. However, increasing trends of total excretion of P was observed in treated Acacia leaf without concentrate supplement followed by 75% untreated Acacia leaves supplements. Urinary P excretion was higher (P<0.05) in untreated 100% ALM than in UL-75 and UL-50 diets. However, the lowest P excretion was reported in treated ALM at 75% level than in TL-100 and TL-50 diets. This could be probably due to concentration of P in the untreated leaf meal as compared to treated Acacia leaves which might be caused by the higher level of Ca in treated groups (Alam *et al.* 2005; Barman and Rai, 2008). Phosphorous retention was higher (P<0.05) in 75% level treated ALM and untreated ALM than the rest of the diets. The result indicats that treatment by $Ca(OH)_2$ treatment improved phosphorous retention. In addition, it was observed that *Acacia toritlis* leaves had higher amount of phosphorous. Thus, P retention was higher in the untreated 100% ALM (Alam *et al.* 2005; Bensalem *et al.* 2006).

Rumen fermentation parameters

The pH and ammonia concentration of rumen liquor of goats fed on the experimental diets are given in Table 8. The pH right before the morning meal was approaching neutral and was similar across diets. The pH was slightly reduced from 2 to 12 hrs after feeding. At 4 hrs of feeding pH was higher (P<0.05) for TL-25 and TL-100 than UL-25 and TL-50 diets. At 4 h after feeding, the rumen pH was slightly higher (P<0.05) for UL-25 than TL-100.The remaining diets had similar pH. At 6 h after feeding, the rumen pH was similar among the treatment diets (P>0.05). At 8 h after feeding, the pH was lower (P<0.05) for UL-50 than UL-25, UL-75, TL-25 and TL-100 whereas UL-25, UL-50 and TL-100 had similar pH values. In addition, UL-50, UL-100, TL-50 and TL-75 had comparable pH values. At 12 h after feeding, pH was higher (P<0.05) for UL-50, TL-50 and TL-100. The remaining diets had comparable pH values.

The pH in the current study was between 6.69 and 6.92 which is within the normal range of pH (6.7-7.1) required for cellulolytic activity and it was above the minimum level of pH (6.1) required for microbial protein synthesis (Stewart *et al.* 2000). pH below 6.1 was reported to inhibit rumen microbial activity. The pH values of UL-50 and TL-75 were found to be higher with maximum ammonia N production throughout the sampling periods.

The mean concentration of rumen NH_3-N was lower (P<0.05) for UL-100 than UL-25. However, the remaining diets had similar concentration. The rumen NH_3-N concentration right before the morning meal was not significant (P>0.05) among the treatment diets. At 2 h of feeding, the NH_3-N concentration was significantly (P<0.05) higher for UL-25 than UL-50, UL-100, TL-25 and TL-100. The rest of the experimental diets had similar concentration. The NH_3-N concentration reached the peak values across the diets at 4h after feeding and decreased thereafter. The NH_3-N concentration was significantly lower for UL-75 and TL-100 but the remaining diets had similar concentration. At 6 h of feeding, the NH_3-N concentration was higher for UL-25 than TL-25. The rest of the experimental diets had similar concentration.

At 8h of feeding, the rumen ammonia concentration was significantly lower for UL-100 than the rest of the experimental diets. Generally, the rumen ammonia concentration increased from 2 h to 6 h of feeding and decreased thereafter. Changes in rumen ammonia of untreated ALM diets ranged from 0 mg/L in UL-100 to 15.5 mg/L in UL-50 from 2 h to 12 h after feeding of the experimental diets. An increase of 0 to 13.3% in NH_3-N concentration was observed in this experiment due the effects of treated ALM diets fed to the goats.

Rumen NH_3-N concentration (136-145 mg/L) in the current study was well above the range of 50-60 mg/L rumen fluid required for optimum microbial protein synthesis (Satter and Slyter, 1974). The NH_3-N concentration in the current study was more than double the optimum level which is an indication of increased protein degradation with limited energy supply in the rumen for proportional NH_3-N production. Thus, increased NH_3-N production with low N excretion were observed in T3 and T8 which further clarifies the level of Acacia leaf supplement as the optimum level of replacement for better utilization by ruminant livestock. Treatment with $Ca(OH)_2$ and partial substitution of the concentrate mixture with ALM increased the NH_3-N concentration. This could be an indication that $Ca(OH)_2$ reacted with tannins and released nitrogen for degradation. The extent of the improvement in fermentation of these tree leaves by addition of $Ca(OH)_2$ probably depended on the level of condensed tannins in the treatment diets and the amount of leaf meal in the concentrate mixtures.

Table 8 Rumen pH of Arsi-Bale goats fed on a basal diet of Rhodes grass hay supplemented by different proportion of concentrate mixture and untreated or calcium hydroxide treated *Acacia toritilis* leaves

Variables	Ca(OH)2 treatment	Level of leaf replacement in concentrate mixture (%)					Mean±SE
		0	25	50	75	100	
Rumen Ph							
0 hr	UL	6.91	6.83	6.90	6.82	6.89	**6.85±0.01**
	TL	6.91	6.90	6.81	6.91	6.92	**6.86±0.01**
	Mean±SE	**.91±0.03**	**6.87±0.14**	**6.86±0.13**	**6.87±0.11**	**6.91±0.27**	
2 hr	UL	6.78	6.78	6.82	6.82	6.81	**6.80±0.01**
	TL	6.78	6.83	6.78	6.81	6.83	**6.82±0.01**
	Mean±SE	**6.78±0.03**	**6.81±0.32**	**6.8±0.17**	**6.82±0.27**	**6.82±0.21**	
4 hr	UL	6.73	6.78	6.83	6.76	6.77	**6.79±0.02**
	TL	6.73	6.78	6.76	6.80	6.72	**6.76±0.02**
	Mean±SE	**6.73±0.05**	**6.78±0.11**	**6.80±0.18**	**6.78±0.02**	**6.75±0.09**	
6 hr	UL	6.72	6.73	6.76	6.75	6.73	**6.74±0.02**
	TL	6.72	6.76	6.70	6.77	6.73	**6.74±0.1**
	Mean±SE	**6.72±0.04**	**6.75±0.21**	**6.73±0.32**	**6.76±0.11**	**6.73±0.17**	
8 hr	UL	6.62^{b}	6.68^{b}	6.79^{a}	6.66^{bB}	6.77^{aA}	**6.73±0.02**
	TL	6.62^{b}	6.68^{b}	6.71^{ab}	6.78^{aA}	6.66^{bB}	**6.71±0.02**
	Mean±SE	**6.62±0.05**	**6.68±0.36**	**6.75±0.04**	**6.72±0.05**	**6.72±0.04**	
12 hr	UL	6.45^{b}	6.52^{b}	6.57^{a}	6.51^{b}	6.58^{a}	**6.55±0.02**
	TL	6.45^{b}	6.53^{b}	6.49^{b}	6.57^{a}	6.51^{b}	**6.52±0.02**
	Mean±SE	**6.45±0.05**	**6.53±0.23**	**6.53±0.28**	**6.54±0.19**	**6.55±0.27**	
Rumen ammonia concentration (mg/dL)							
0 hr	UL	127	128	126	125	127	**127±0.61**
	TL	127	128	128	128	127	**128±0.57**
	Mean±SE	**127±0.40**	**128±0.0**	**127±1.32**	**127±1.05**	**127±1.07**	
2 hr	UL	139^{b}	145^{aA}	134^{c}	141^{b}	132^{cB}	**138±1.25**
	TL	139^{b}	136^{cB}	136^{c}	140^{b}	144^{aA}	**139±1.20**
	Mean±SE	**139±0.80**	**141±1.32**	**135±1.45**	**140±1.09**	**137±1.03**	
4 hr	UL	166	159	163	155	159	**159±11.50**
	TL	166	157	156	159	155	**157±1.54**
	Mean±SE	**166±1.00**	**158±1.09**	**160±1.53**	**157±1.45**	**157±1.22**	
6 hr	UL	143^{b}	154^{a}	152^{ab}	144^{b}	137^{bB}	**147±1.60**
	TL	143	152	149	148	149^{A}	**150±1.52**
	Mean±SE	**143±1.10**	**153±0.76**	**151±0.76**	**146±0.45**	**143±0.54**	
8 hr	UL	141^{ab}	147^{a}	146^{a}	139^{ab}	134^{bB}	**142±1.30**
	TL	141	146	143	143	143^{A}	**144±1.25**
	Mean±SE	**141±0.90**	**147±0.07**	**145±0.56**	**141±0.76**	**139±0.67**	
12 hr	UL	135^{ab}	138^{a}	137^{a}	133^{ab}	127^{b}	**134±1.16**
	TL	135	136	135	134	133	**135±1.31**
	Mean±SE	**135±0.80**	**137±0.12**	**136±0.17**	**134±0.54**	**130±0.18**	

$^{a, b, c, d}$: the means within the same row with different letter, are significantly different (P<0.05).
$^{A, B}$: the means within the same column with different letter, are significantly different (P<0.05).
SE: standard error.
UL-0: hay + 300 g concentrate; UL-25: hay + 225 g concentrate and 75 g untreated dried leaves; UL-50: hay + 150 g concentrate and 150 g untreated dried leaves; UL-75: hay + 75 g concentrate and 225 g untreated dried leaves; UL-100: hay + 300 g untreated dried leaves; TL-0: hay + 300 g concentrate; TL-25: hay + 225 g concentrate and 75 g dried treated leaves; TL-50: hay + 150 g concentrate and 150 g treated dried leaves; TL-75: hay + 75 g concentrate and 225 g treated dried leaves and TL-100: hay + 300 g treated dried leaves.

Barman and Rai (2008) reported that there was increased NH_3-N concentrations with addition of $Ca(OH)_2$ as a result of increased CP degradability and/or poor synchronization between N and carbohydrate release in the rumen. If rapid release of N does not match availability of carbohydrate it can lead to accumulation of NH_3-N *in vitro* or to high absorption of NH_3-N from the rumen *in vivo* (Abdulrazak *et al.* 2000). Thus, higher levels of NH_3-N suggest that utilization of *Acacia toritlis* leaves can be improved by $Ca(OH)_2$ treatment. Because calcium hydroxide has a higher capacity to deactivate free extractable tannins, versus bound tannins from fiber and reduce their negative effects, which may reflect the negative relationship between fermentation parameters and phenolic composition of the experimental diets (Alam *et al.* 2005).

CONCLUSION

The CP content of *Acacia toritilis* leaves in the current experiment is approximately three times that of indigenous

grass species in the rangeland. Partial substitution of air dried leaves in the concentrate mixture could be utilized as supplement to the basal hay at 50% level without treatment or up to 75% level with calcium hydroxide treatment for better performance of Arsi-Bale breed of goats. Thus, this browse species could be an option for dry season feeding to ruminants provided that the anti-nutrient factor present in the leaves are diluted by mixing with concentrate or treated with tannin deactivating agents such as $Ca(OH)_2$ treatments. In addition, optimum mixture of leaves and pods of browse species for different species of livestock as feed supplement to basal rangeland grasses, is suggested for effective livestock production in the dry land tropics. Therefore, knowledge of concentration of CT in browse spp. and identification of potential inclusion levels in ruminant diets would be a good strategy for effective utilization of such resources.

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