EFFECTS OF MIXTURE LEVEL OF SORGHUM HAY WITH FORAGE LEGUMES ON PERFORMANCE AND BLOOD METABOLITES OF YEARLING INDIGENOUS PEDI BUCKS

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(Received 5th Dec 2017; accepted 7th Mar 2018)

Abstract. Four experiments were conducted at the University of Limpopo Experimental farm, Limpopo province, South Africa to determine the effect of legume inclusion on the performance of Pedi bucks on a basal diet of forage sorghum hay. *Vigna ungiculata* (cowpea), *Lablab purpureus* (lablab) and *Mucuna pruriens* (mucuna) hays were used in this trial at different inclusion levels. Fifteen yearling Pedi bucks with average weights of 15 ± 4 kg (Experiment 1), 18 ± 2 kg (Experiment 2) and 17 ± 3 kg (Experiment 3) were used in the first three experiments in a completely randomised design. Nine goats with an average weight of 20 ± 4 kg were used in Experiment 4. Mucuna hay had the highest ($P < 0.05$) hydrolysable tannin contents. Lablab hay had higher ($P < 0.05$) total polyphenolics than mucuna, cowpea and sorghum hays. Dry matter intake and digestibility increased with increasing levels of the respective forage inclusion levels. Cowpea and mucuna hay improved ($P < 0.05$) final live weights and feed conversion ratio, while goats on lablab hay lost weight. Diet intake, digestibility and final live weights of the goats were optimized at different forage inclusion levels. This may indicate that legume inclusion levels for optimal productivity will depend on the particular parameter of interest.
Keywords: *legume inclusion, optimal intake, polyphenolic, digestibility, goats*

Introduction

Goats are economically, nutritionally and culturally important livestock species among the agrarian rural communities of South Africa. Additionally, the indigenous Pedi goats in Limpopo Province of South Africa constitute a valuable source of genetic material because of their relative adaptation to harsh climatic conditions and their ability to better utilise the limited and poor quality feed resources (Brown and Ngambi, 2017). However, their productivity is limited by acute shortages of good quality feed, especially during the dry and winter seasons (Brown et al., 2017). Available fodder during this period is fibrous and low in nitrogen resulting in low voluntary intake and digestibility (Tolera et al., 2000). Poor nutrition results in loss of body weight and reproductive performance (Matlebyane et al., 2010). Supplementation with forage legumes may be appropriate alternative for increasing intake and digestibility of these poor quality roughages (Mupangwa, 2002).

Forage legumes such as *Vigna ungiculata* (cowpeas), *Lablab purpureus* (lablab) and *Mucuna pruriens* (mucuna) are commonly grown by farmers in Limpopo province of South Africa. These legumes have high nitrogen contents and hence there is potential to increase the productivity of indigenous goats feeding on low quality roughages. Legumes can supply the limiting nitrogen in the form of amino acids and peptides. Abule et al. (1995) reported increased total dry matter (DM) intake in calves fed straw supplemented with either cowpea or lablab hay. Umunna

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

et al. (1995) reported increased average daily gain in sheep fed oat hay supplemented with lablab leaf meal. Similar results were reported in sheep fed scrubland herbage supplemented with lablab leaf meal (Ndlovu and Sibanda, 1996). Mupangwa et al. (2002) concluded that inclusion of *Mucuna pruriens*, (mucuna) in low quality grass hay diets increased protein availability in sheep by increasing the supply of both rumen degradable and undegradable proteins. However, some of these legumes may contain polyphenolic compounds which may reduce diet intake and digestibility (Reed, 1995). The effects of such compounds in tropical legumes on diet intake and digestibility have not been extensively studied in indigenous goat breeds. Thus, extensive evaluation of these forage legumes in terms of their polyphenolic effects on diet intake, digestibility and productivity is appropriate. Therefore, the objective of this study was to determine the effect of mixture level of forage sorghum with cowpea, lablab or mucuna legumes on diet intake, digestibility growth and blood metabolites of indigenous Pedi goats of South Africa.

Materials and methods

Study site

This study was conducted at the University of Limpopo Experimental Farm, South Africa (latitude 27°55 S and longitude 24°77 E). The ambient temperature at the study site ranges between 20 and 36°C in summer (November - January) and between 5 and 25 °C in winter (May – July). Mean annual rainfall ranges between 446.8 and 468.44 mm. The vegetation is a mixture of shrubs (mainly *Vachellia* species), trees and grass.

Forages

Forage sorghum, cowpea (*Vigna ungiculata*), lablab (*Lablab purpureus*) and mucuna (*Mucuna pruriens*) hays were grown in large plots under irrigation in January, 2012. At harvesting, the legumes were at the flowering stage while forage sorghum was at early grain filling stage. The forages were harvested using a mower, and dried under the shade to prevent nutrient loss. After drying, the forages were chopped (12.7 mm length) to reduce selection by animals when feeding (Mentu et al., 2001). The dried and chopped forages were then thoroughly mixed according to the different ratios and packed into sacks as hay for winter-feeding.

Experimental procedures, treatments and designs

This study was divided into a series of experiments due to lack of equipment to conduct the whole study in one session. The experimental design was a completely randomized design, with individual animals placed in metabolic cages as experimental units. A total of four experiments were conducted. Experiments 1 to 3 involved cowpea, lablab and mucuna hays, respectively, while Experiment 4 determined the inclusion level for optimal intake from each of the first three experiments, as indicated below. The dietary treatments for optimal intake were determined from the quadratic equations described under statistical analysis. The experimental treatments were as listed below:

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

Experiment 1	**Treatments**
Code	**Description of the treatment**
$FS_{90}C_{10}$	A mixture of 90% forage sorghum and 10% cowpea
$FS_{80}C_{20}$	A mixture of 80% forage sorghum and 20% cowpea
$FS_{70}C_{30}$	A mixture of 70% forage sorghum and 30% cowpea
$FS_{60}C_{40}$	A mixture of 60% forage sorghum and 40% cowpea
$FS_{50}C_{50}$	A mixture of 50% forage sorghum and 50% cowpea
Experiment 2	**Treatments**
Code	**Description of the treatment**
$FS_{90}L_{10}$	A mixture of 90% forage sorghum and 10% lablab
$FS_{80}L_{20}$	A mixture of 80% forage sorghum and 20% lablab
$FS_{70}L_{30}$	A mixture of 70% forage sorghum and 30% lablab
$FS_{60}L_{40}$	A mixture of 60% forage sorghum and 40% lablab
$FS_{50}L_{50}$	A mixture of 50% forage sorghum and 50% lablab
Experiment 3	**Treatments**
Code	**Description of the treatment**
$FS_{90}M_{10}$	A mixture of 90% forage sorghum and 10% mucuna
$FS_{80}M_{20}$	A mixture of 80% forage sorghum and 20% mucuna
$FS_{70}M_{30}$	A mixture of 70% forage sorghum and 30% mucuna
$FS_{60}M_{40}$	A mixture of 60% forage sorghum and 40% mucuna
$FS_{50}M_{50}$	A mixture of 50% forage sorghum and 50% mucuna
Experiment 4	**Treatments**
Code	**Description of the treatment**
$S_{61}C_{39}$	A mixture of 61% forage sorghum and 39% cowpea
$S_{68}L_{32}$	A mixture of 68% forage sorghum and 32% lablab
$S_{77}M_{23}$	A mixture of 77% forage sorghum and 23% mucuna

Animals

All procedures involving animals were approved by the Animal Research Ethics Committee of the University of Limpopo, South Africa. Fifteen growing yearling Pedi bucks (a local breed in Limpopo province of South Africa) with mean live weights of 15 ± 4 kg (Experiment 1), 18 ± 2 kg (Experiment 2), and 17 ± 3 kg (Experiment 3) were used. Nine goats with a mean live weight of 20 ± 4 kg were used in Experiment 4. In each experiment, different goats were used but of similar ages. Thus, a total of 54 goats were used in the study. Each treatment had three replicates with one goat per replicate as described by Brown and Ng'ambi (2017). The animals were housed in individual metabolic cages that allowed the separation of faeces and urine (5.5ˈ x 2.0ˈ) and were given the experimental diets during the study period. The goats were drenched with an anthelmintic (Valbazen® broad-spectrum dewormer, Pfizer Inc, NY, USA) before the start of the experiment.

An adjustment period of 2 weeks allowed goats to become acclimatized to the metabolic cage before the start of the study. Each goat was initially fed 700 g of feed per day in individual troughs. This amount was adjusted accordingly so that a 10% feed refusal was maintained to avoid selection. Goats were fed once a day at 08.00 hours and feeds offered and refused were determined. Each experiment lasted for 21 days, the last 7 days being collection period. Animals had access to feed and water *ad libitum*. The goats were weighed weekly. Average daily gain was determined. The weighing of the goats was carried out before morning feeding to avoid feed effect (Sarwatt et al., 2003). Feeds were collected from each diet and stored for laboratory analysis. During collection, daily faecal outputs for each animal

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

were collected, mixed and recorded. Ten percent of the faeces were sub-sampled and kept for analysis. All the sub-sampled faeces were pooled on animal basis, dried and kept until required for chemical analysis. From the food eaten and faecal matter secreted, apparent digestibility of the nutrients was calculated (McDonald et al., 2010). Blood samples were taken from each goat via the jugular vein just before the morning feeding on the first and last day of the experiment (Olafadehan, 2011). The blood samples were collected from each animal, before feeding at the beginning and end of the study, into anticoagulant free bottles, allowed to coagulate at room temperature and centrifuged at 1500ˈx *g* for 10 min. The supernatant sera were then harvested and stored at -20°C for subsequent analysis.

Laboratory analyses

Samples of the forages (cowpea, lablab, mucuna and sorghum) were ground to pass a 1 mm screen for nutrient analysis. Samples for tannin analysis were further ground to pass through a 0.2 mm screen. Dry matter of feeds, refusals and faeces were determined by the method described by AOAC (2005). Ash was determined by the method described by AOAC (2005). Acid detergent fibre and neutral detergent fibre were determined by the method described by Van Soest et al. (1991). Nitrogen content was determined for feeds and faeces using the Kjedahl procedure (AOAC, 2005). Sodium oxalate fluoride was used for glucose preservation, while the blood glucose was determined by enzymatic colorimetric test (Quimica Clinical Applicada, SA). Serum urea was obtained by the method of Valley et al. (1980). Extraction of polyphenolics from plant material was done using the method described by Makkar et al. (1995). Condensed tannins, hydrolysable tannins and total polyphenols were determined using the methods described by Porter et al. (1986).

Statistical analysis

All data on diet intake, digestibility, weight change, feed conversion ratio, nitrogen balance, and blood metabolites were analysed using the General Linear Model procedures of SAS (SAS, 2010). Covariance analysis was done using initial bodyweight of the goats as covariate. Treatment means were compared using Tukey's HSD and significant differences were declared at $P < 0.05$. The responses in optimal intake, digestibility, weight change, feed conversion ratio, nitrogen balance, and blood metabolites were modelled using the following quadratic equation:

$$Y = a + b_1 x + b_2 x^2$$

where Y = Intake, digestibility, weight change, feed conversion ratio, nitrogen balance or blood metabolites; a = intercept; b = coefficients of the quadratic equation; x = level of inclusion and $-b_1/2b_2$ = level of inclusion value for optimal production response (Brown and Ng'ambi, 2017).

Results

Nutrient composition of feeds

Results of the chemical composition of the experimental feeds are presented in *Table 1*. Cowpea, lablab and mucuna hay had higher ($P < 0.05$) protein contents than sorghum hay. There were traces of tannins and polyphenolic compounds in all the forages. However,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

mucuna hay had higher (P < 0.05) condensed and hydrolysable tannin contents when compared to sorghum, lablab and cowpea. Lablab hay had higher (P < 0.05) total polyphenolics (1.24 mg/g) when compared to mucuna (0.35 mg/g), cowpea (0.05 mg/g) and sorghum (0.17 mg/g) hays. Cowpea hay had lower (P < 0.05) total polyphenolics, condensed and hydrolysable tannin contents.

Table 1. *The chemical composition of the experimental feeds*[#]

Nutrient (% DM)	Forage				SEM	Probability
	Cowpea	Lablab	Mucuna	Sorghum		
Dry matter	90	93	94	94	2.10	NS
Organic matter	83[c]	87[b]	90[a]	90[a]	1.50	*
Crude protein	22[a]	19[b]	18[c]	13[d]	0.00	*
Neutral detergent fibre	38[bc]	34[c]	40[b]	64[a]	1.82	*
Acid detergent fibre	32[bc]	31[c]	36[b]	52[a]	2.35	*
Condensed tannins[##]	0.03[d]	0.05[c]	0.40[a]	0.06[b]	0.00	*
Hydrolysable tannins (mg/g)	81.3[d]	113.3[b]	284.3[a]	111.1[c]	1.30	*
Total polyphenols (mg/g)	0.05[d]	1.24[a]	0.35[b]	0.17[c]	0.00	*

SEM: Standard error of the mean
[#]Four samples per replicate were used
[##]Condensed tannins as percentage DM leucocyanidin equivalent
[a,b,c]Means in the same row with different superscripts are significantly different
NS: Not significant
*P < 0.05

Cowpea inclusion

The results of the effect of cowpea hay inclusion level on diet intake, digestibility, live weight change, nitrogen balance and blood serum chemistry of indigenous Pedi bucks fed a basal diet of forage sorghum hay are presented in *Table 2*. Daily dry matter intakes of cowpea were similar (P > 0.05) across dietary treatments, ranging from 370 to 511 g per goat per day. Similarly, goats consumed similar (P > 0.05) amounts of organic matter (OM) and neutral detergent fibre (NDF) contents. However, Pedi bucks on diets 20, 30, 40 or 50% cowpea hay inclusion levels had higher (P < 0.05) crude protein (CP) and acid detergent fibre (ADF) intakes than those on diets with 10% cowpea hay. Pedi goats on a diet with 50% cowpea hay inclusion level had higher (P < 0.05) DM, OM and CP intakes per metabolic weight as compared to those on other dietary treatments. Goats on diets having a 30% cowpea hay inclusion level had lower (P < 0.05) NDF and ADF intakes per metabolic weight than those on other dietary treatments. Dry matter, OM, NDF and ADF digestibility values were similar (P > 0.05) across the dietary treatments. However, goats on diets having 20, 40 or 50% cowpea hay inclusion levels had higher (P < 0.05) dietary CP digestibility values than those on diets having 10 or 30% cowpea hay inclusion levels. Pedi goats fed diets having 20, 30, 40 or 50% cowpea hay inclusion levels had higher (P < 0.05) nitrogen intakes than those on a diet with 10% cowpea hay inclusion level. Similarly, goats on diets having 20, 40 or 50% cowpea hay inclusion levels retained higher (P < 0.05) amounts of nitrogen than those on 10 or 30% cowpea diets. Cowpea inclusion level did not (P > 0.05) have effects on blood glucose concentration of the bucks. However, goats fed diets having 20, 40 or 50% cowpea hay inclusion levels had higher (P < 0.05) blood

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

urea than those on diets with 10 or 30% cowpea hay inclusion levels. Cowpea hay inclusion level did not (P > 0.05) have effect on weight gain of goats. However, dietary treatment had effect (P < 0.05) on the final live weight of goats. Goats fed diets having a 10% cowpea hay inclusion level had the lowest final weight as compared to those on 30% inclusion level. Feed conversion ratio was improved (P < 0.05) in goats fed diets having a 50% cowpea hay inclusion level. Cowpea hay inclusion levels of 39, 39, 54 and 33% optimized DM, OM, CP and ADF intakes while nitrogen retention and blood glucose were optimized at 56 and 33% levels, respectively (*Table 3*).

Table 2. *Effect of cowpea hay inclusion levels on diet intake, digestibility, live weight change, nitrogen balance and blood metabolic profiles of Pedi bucks fed a basal diet of forage sorghum hay*

Variable	**Treatment**					**SEM**	**P**
	$FS_{90}C_{10}$	**$FS_{80}C_{20}$**	**$FS_{70}C_{30}$**	**$FS_{60}C_{40}$**	**$FS_{50}C_{50}$**		
Intake (g/goat/day)							
Dry matter	370	511	469	476	500	50.59	NS
Organic matter	320	426	394	395	417	40.49	NS
Crude protein	53^{b}	76^{a}	74^{a}	79^{a}	88^{a}	7.53	*
Neutral detergent fibre	370	345	285	291	292	36.09	NS
Acid detergent fibre	194^{b}	283^{a}	245^{a}	247^{a}	242^{a}	24.34	*
Intake ($g/kgW^{-0.75}$)							
Dry matter	80^{d}	99^{b}	80^{d}	93^{c}	101^{a}	0.28	*
Organic matter	70^{d}	83^{b}	68^{e}	75^{c}	85^{a}	1.01	*
Crude protein	12^{d}	14^{bc}	13^{cd}	17^{ab}	18^{a}	1.02	*
Neutral detergent fibre	81^{a}	68^{b}	48^{e}	56^{d}	59^{c}	0.68	*
Acid detergent fibre	43^{d}	55^{a}	42^{e}	48^{c}	49^{b}	0.30	*
Digestibility (decimal)							
Dry matter	0.57	0.67	0.65	0.69	0.65	0.04	NS
Organic matter	0.59	0.66	0.59	0.65	0.68	0.07	NS
Crude protein	0.70^{b}	0.76^{a}	0.69^{b}	0.80^{a}	0.75^{a}	0.03	*
Neutral detergent fibre	0.65	0.69	0.59	0.66	0.62	0.07	NS
Acid detergent fibre	0.43	0.52	0.40	0.50	0.53	0.01	NS
N-intake (g/goat/day)	8.4^{b}	12.1^{a}	11.8^{a}	12.7^{a}	14.0^{a}	1.20	*
N-retention (g/goat/day)	5.9^{c}	9.2^{ab}	8.2^{b}	10.1^{a}	10.5^{a}	1.01	*
Blood metabolites (mmol/L)							
Blood glucose	2.5	3.3	3.1	3.4	3.4	0.37	NS
Blood serum urea	7.3^{c}	7.8^{ab}	6.6^{c}	7.3^{ab}	8.3^{a}	0.5	*
Live weight							
Initial (kg/goat)	14.9	17.7	19.7	16.7	15.0	0.92	NS
Final (kg/goat)	15.6^{b}	18.2^{ab}	20.4^{a}	17.4^{ab}	16.03^{ab}	1.42	*
Gain (g/goat/day)	140	100	140	140	212	308.1	NS
Feed conversion ratio	2.57^{c}	5.11^{a}	3.35^{b}	3.40^{b}	2.36^{d}	0.002	*

SEM: Standard error of the means
[a,b,c]Means in the same row with different superscripts are significantly different
P: Probability
NS: Not significant
*P < 0.05

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

***Table 3.** Cowpea hay inclusion levels for optimal diet intake, nitrogen retention and blood glucose in Pedi bucks on a basal diet of forage sorghum hay*

Factor	Formula	Ratio level	Y- Level	r^2	P
Intake (g/goat/day)					
DM	$Y=320.747+9.279x+ -0.120x^2$	38.66	500	0.307	0.111
OM	$Y=274.000+7.416x + -0.096x^2$	38.63	417	0.568	0.432
CP	$Y=41.600+1.630x+ -0.015x^2$	54.33	56	0.847	0.153
ADF	$Y=150.200+6.943x+ -0.106x^2$	32.75	264	0.479	0.521
N-retention (mmol/L)					
	$Y=4.300x+0.225x+ -0.002x^2$	56.25	11	0.599	0.200
Blood glucose (mmol/L)					
	$Y=2.020+0.066x+ -0.001x^2$	33.00	3	0.782	0.218

r^2: Coefficient of determination
P: Probability

Lablab inclusion

The results of the effect of lablab hay inclusion level on dietary intake, digestibility, live weight change, nitrogen balance and blood serum chemistry of indigenous Pedi bucks fed a basal diet of forage sorghum hay are presented in *Table 4*.

***Table 4.** Effect of lablab hay inclusion levels on diet intake, digestibility, live weight change, nitrogen balance and blood metabolic profiles of Pedi bucks fed a basal diet of forage sorghum hay*

Variable	Treatment					SEM	P
	$FS_{90}L_{10}$	$FS_{80}L_{20}$	$FS_{70}L_{30}$	$FS_{60}L_{40}$	$FS_{50}L_{50}$		
Intake (g/goat/day)							
DM	517	552.	583	565	539	55.63	NS
OM	324	465	494	489	434	75.71	NS
CP	70	78	86	87	86	8.08	NS
NDF	424	402	400	378	337	30.56	NS
ADF	191	227	217	214	211	17.50	NS
Intake ($g/kgW^{-0.75}$)							
DM	92^{c}	100^{bc}	111^{ab}	112^{a}	104^{ab}	5.38	*
OM	57^{d}	84^{c}	93^{b}	97^{a}	85^{c}	0.93	*
CP	14^{c}	14^{b}	17^{a}	17^{a}	17^{a}	0.75	*
NDF	76	72	67	75	65	7.57	NS
ADF	33^{b}	40^{a}	41^{a}	43^{a}	41^{a}	1.33	*
Digestibility (decimal)							
DM	0.66	0.67	0.68	0.69	0.70	0.02	NS
OM	0.58	0.63	0.74	0.73	0.69	0.10	NS
CP	0.72^{b}	0.73^{b}	0.77^{a}	0.79^{a}	0.78^{a}	0.02	*
NDF	0.74	0.71	0.78	0.73	0.71	0.05	NS
ADF	0.22	0.27	0.73	0.59	0.54	0.23	NS
N-intake (g/goat/day)	11.3	12.5	13.8	13.8	13.9	1.29	NS
N-retention (g/goat/day)	8.1^{c}	9.1^{bc}	10.6^{ab}	11.1^{a}	10.7^{a}	0.83	*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

Blood metabolites (mmol/L)							
Blood glucose	2.7	2.9	3.3	2.3	3.2	0.53	NS
Blood urea	5.9	7.9	7.0	7.4	7.9	1.25	NS
Live weight							
Initial (kg/goat)	19.7	20.4	17.9	18.3	18.6	1.92	NS
Final (kg/goat)	19.5	19.5	17.8	18	18	1.71	NS
Loss (g/goat/day)	-40	-180	-20	-60	-120	318.1	NS

SEM: Standard error of the means
[a,b,c]Means in the same row with different superscripts are significantly different.
P: Probability
NS: Not significant
*P < 0.05

Daily DM, OM, CP, NDF and ADF intakes were similar (P > 0.05) across dietary treatments. Pedi goats fed a diet having a 40% lablab hay inclusion level had higher (P < 0.05) dry matter intakes per metabolic weight than those on 10 or 20% inclusion levels. Goats fed diets having 30, 40 or 50% lablab hay inclusion levels had higher (P < 0.05) CP intakes per metabolic weight than those on other dietary treatments. Pedi goats had similar (P > 0.05) DM, OM, NDF and ADF digestibility values across the dietary treatments. Goats on diets having 30, 40 or 50% lablab hay inclusion levels had higher (P < 0.05) crude protein digestibility values than those on diets having 10 or 20% lablab hay inclusion levels. Daily nitrogen intakes were similar (P > 0.05) across dietary treatments. However, goats fed diets having 40 or 50% lablab hay inclusion levels had higher (P < 0.05) nitrogen retention values than those on 10 or 20% lablab hay inclusion levels. Lablab hay inclusion level did not have effect (P > 0.05) on blood glucose and serum urea of goats. Similarly, lablab hay inclusion level did not have effect (P > 0.05) on the live weights of Pedi goats. However, weight losses were observed across all dietary treatments. Dry matter, OM, CP and ADF intakes were optimized at 32.29, 34.04, 41.14 and 32.48% lablab hay inclusion levels, respectively, while nitrogen retention was optimized at 39.17% lablab hay inclusion level (*Table 5*).

Table 5. *Lablab hay inclusion levels for optimal diet intake and nitrogen retention in Pedi bucks on a basal diet of forage sorghum hay*

Factor	Formula	Ratio level	Y- Level	r^2	P
Intake (g/goat/day)					
DM	$Y=448.913+7.879x+ -0.122x^2$	32.29	576	0.532	0.010
OM	$Y=155.000+20.697x+ -0.304x^2$	34.04	507	0.974	0.026
CP	$Y= 56.600+1.481x+ -0.018x^2$	41.14	87	0.989	0.011
ADF	$Y=168.400+3.313x+ -53.80x^2$	32.48	222	0.622	0.378
Intake ($g/kgW^{-0.75}$)					
DM	$Y=72.000+2.160x+ -0.030x^2$	36	111	0.937	0.63
OM	$Y=21.000+4.247x+ -0.059x^2$	36	97	0.991	0.009
ADF	$Y=25.400+0.919x+ -0.012x^2$	38.29	43	0.958	0.042
N-retention (mmol/L)					
	$Y=5.860+0.235x+ -0.003x^2$	39.17	11	0.964	0.036

r^2: Coefficient of determination
P: Probability

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

Mucuna inclusion

The results of the effect of mucuna hay inclusion level on dietary intake, digestibility, live weight change, nitrogen balance and blood serum chemistry of indigenous Pedi bucks fed a basal diet of forage sorghum hay are presented in *Table 6*.

Table 6. *Effect of mucuna hay inclusion levels on diet intake, digestibility, live weight change, nitrogen balance and blood metabolic profiles of Pedi bucks fed forage sorghum hay*

Variable	Treatment					SEM	P
	$FS_{90}M_{10}$	$FS_{80}M_{20}$	$FS_{70}M_{30}$	$FS_{60}M_{40}$	$FS_{50}M_{50}$		
Intake (g/goat/day)							
DM	468	460	447	492	550	41.11	NS
OM	405	400	393	430	482	0.106	NS
CP	63^{b}	64^{b}	65^{b}	74^{b}	85^{a}	5.921	*
NDF	341	343	343	334	364	32.66	NS
ADF	180	180	176	189	184	14.86	NS
Intake ($g/kgW^{-0.75}$)							
DM	79^{e}	92^{c}	85^{d}	102^{a}	95^{b}	1.03	*
OM	68^{e}	80^{c}	75^{d}	89^{a}	84^{b}	0.23	*
CP	11^{c}	13^{b}	13^{b}	16^{a}	15^{ab}	0.98	*
NDF	58^{e}	69^{b}	66^{c}	70^{a}	64^{d}	0.09	*
ADF	30^{d}	36^{b}	33^{c}	40^{a}	33^{c}	1.02	NS
Digestibility (decimal)							
DM	0.59	0.60	0.59	0.62	0.62	0.02	NS
OM	0.64^{a}	0.60^{bc}	0.57^{c}	0.65^{ab}	0.69^{a}	0.03	*
CP	0.68	0.68	0.67	0.68	0.71	0.02	NS
NDF	0.67	0.63	0.48	0.65	0.67	0.11	NS
ADF	0.17	0.12	0.32	0.24	0.33	0.16	NS
N-intake (g/goat/day)	10.1^{b}	10.3^{b}	10.4^{b}	11.8^{b}	13.6^{a}	0.95	*
N-retention (g/goat/day)	6.0^{bc}	7.0^{b}	7.0^{b}	8.0^{b}	9.7^{a}	0.70	*
Blood metabolites (mmol/L)							
Blood glucose	2.8^{c}	3.7^{c}	3.3^{c}	4.0^{ab}	4.5^{a}	1.03	*
Blood urea	7.9^{bc}	9.7^{a}	8.6^{b}	9.7^{a}	9.8^{a}	1.12	*
Live weight							
Initial (kg/goat)	20.5	16.8	17.8	16.1	19.0	1.09	NS
Final (kg/goat)	21.1^{a}	17.5^{b}	18.6^{ab}	17.1^{b}	19.9^{a}	1.37	*
Gain (g/goat/day)	120	140	183	200	180	118.6	NS
Feed conversion ratio	3.90^{a}	3.29^{ab}	2.44^{c}	2.46^{c}	3.06^{bc}	0.39	*

SEM: Standard error of the means
[a,b,c]: Means within a row with different superscripts differ significantly
P: Probability
NS: Not significant
*$P < 0.05$

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DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

Daily DM, OM, NDF and ADF intakes were similar (P > 0.05) across the dietary treatments. However, goats on a diet having 50% mucuna hay inclusion level had higher (P < 0.05) crude protein intakes than those on diets having 10, 20, 30 or 40% dietary treatments. Goats on a diet having a 40% mucuna hay inclusion level had higher (P < 0.05) DM, OM, CP, NDF and ADF intakes per metabolic weight than those on other dietary treatments. Similarly, goats on a diet with 50% mucuna hay inclusion level had higher (P < 0.05) DM and OM intakes per metabolic weight than those on 10, 20 or 30% inclusion levels. Goats had similar (P > 0.05) DM, CP, NDF and ADF digestibility values across dietary treatments. However, goats on diets with 10 or 50% mucuna hay inclusion levels had higher (P < 0.05) OM digestibility than those on other dietary treatments. Goats on diets having a 50% mucuna hay inclusion level had higher (P < 0.05) nitrogen intake and nitrogen retention than those on diets with 10, 20, 30 or 40% inclusion levels. Goats on diets with 40 or 50% mucuna hay inclusion levels had higher (P < 0.05) blood glucose than those on 10, 20 and 30% inclusion levels. Similarly, goats on diets having 20, 40 or 50% mucuna hay inclusion levels had higher (P < 0.05) serum urea concentrations than those on 10 or 30% inclusion levels. Goats on diets having 10 or 50% mucuna hay inclusion levels had higher (P < 0.05) final body weights than those on other dietary treatments. Goats on diets having 30 or 40% mucuna hay inclusion levels had better (P < 0.05) feed conversion ratio than those on 10, 20 or 50% mucuna hay inclusion levels. Mucuna hay inclusion levels of 50.27, 47.86, 59.75, 33.87 and 35.73% optimized DM, OM, CP, NDF and ADF intakes per metabolic weight of the goats, respectively, while live weight change and feed conversion ratio of the goats were optimized at 41.7 and 41.5% inclusion levels, respectively (*Table 7*).

Table 7. *Mucuna hay inclusion levels for optimal diet intake, live weight change and feed conversion ratio in Pedi goats on a basal diet of forage sorghum hay*

Factor	Formula	Ratio level	Y -Level	r^2	P
Intake ($g/kgW^{-0.75}$)					
DM	$Y=70.000+1.106x+ -0.011x^2$	50.27	99	0.614	0.386
OM	$Y=59.400+1.053x+ -0.011x^2$	47.86	85	0.701	0.299
CP	$Y=8.800+0.239x+ -0.002x^2$	59.75	16	0.838	0.162
NDF	$Y=48.000+1.287x+ -0.019x^2$	33.87	70	0.756	0.244
ADF	$Y=23.400+0.786x+ -0.011x^2$	35.73	37	0.495	0.505
LWC (g/d)	$Y=57.600+6.343x+-0.076x^2$	41.7	190	0.91	0.086
FCR	$Y=5.423+-6.89x+3.44x^2$	41.5	2	0.938	0.062

r^2: Coefficient of determination
P: Probability
LWC: Live weight change

Optimal intakes

The results of the effect of cowpea, lablab, and mucuna hay inclusion level at optimal intake are presented in *Table 8*. Daily DM, OM, CP and ADF intakes of the diets were similar (P > 0.05) across dietary treatments. However, goats on diets having cowpea or lablab had higher (P < 0.05) NDF intakes than those on a diet having mucuna hay. Crude protein and ADF intakes per metabolic weight were not affected (P > 0.05)

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by dietary treatment. Pedi goats on diets having cowpea had higher (P < 0.05) DM, OM and NDF intakes per metabolic weight than those on diets having lablab and mucuna hays. Dietary treatments had no effect (P > 0.05) on diet DM, OM, CP, NDF and ADF digestibility. Similarly, dietary treatment had no effect (P > 0.05) on diet nitrogen intake, nitrogen retention and weight gain of the goats. However, goats fed a diet containing lablab had higher (P < 0.05) final body weights than those on diets containing cowpea hay. Goats on a diet having mucuna hay had better (P < 0.05) feed conversion ratio than those on diets containing lablab or cowpea hay.

Table 8. *Effect of cowpea, lablab and mucuna hay inclusion levels on diet intake, digestibility, live weight change and nitrogen balance in Pedi bucks fed forage sorghum hay as a basal diet*

Variable	Treatments			SEM	P
	Cowpea ($S_{61}C_{39}$)	Lablab ($S_{68}L_{32}$)	Mucuna ($S_{77}M_{23}$)		
Intake (g/goat/day)					
DM	521	527	499	58.02	NS
OM	424	434	422	41.53	NS
CP	86	79	71	6.61	NS
NDF	162^{a}	149^{ab}	134^{c}	7.0	*
ADF	134	142	129.41	11.90	NS
Intake (g/kgW$^{-0.75}$)					
DM	91^{a}	73^{c}	81^{b}	0.88	*
OM	74^{a}	60^{c}	68^{b}	0.27	*
CP	15	12	12	1.30	NS
NDF	29^{a}	21^{b}	22^{b}	1.04	*
ADF	24	19	21	1.33	NS
Digestibility (decimal)					
DM	0.51	0.54	0.52	0.05	NS
OM	0.47	0.52	0.50	0.05	NS
CP	0.67	0.73	0.68	0.03	NS
NDF	0.39	0.12	0.19	0.37	NS
ADF	0.28	0.45	0.50	0.33	NS
N-intake (g/goat/day)	13.3	12.6	13.8	1.06	NS
N-retention (g/goat/day)	7.8	8.9	9.4	0.82	NS
Live weight					
Initial (kg/goat)	19.2	24.4	20.1	1.67	NS
Final (kg/goat)	20^{b}	25.4^{a}	21.2^{ab}	1.63	*
Gain (g/goat/day)	160	200	220	251.0	NS
Feed conversion ratio	3.26^{a}	2.64^{b}	2.27^{c}	0.005	*

SEM: Standard error of the means
[a,b,c]: Means within a row with different superscripts differ significantly
P: Probability
NS: Not significant
*P < 0.05

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DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

Discussion

The legume species have higher protein contents (18% and above) than sorghum hay (13%). The protein values of cowpea, lablab and mucuna hays were similar to the protein values reported by Nielsen et al. (1997) and Adjorlolo et al. (2001), respectively. Thus, these legumes can be used as protein supplements where low quality roughage is used as a basal diet for goats. Forage sorghum hay contained higher amounts of acid detergent fibre than the legumes. Higher acid detergent fibre contents may indicate lower digestibility values (Buxton et al., 1996). Lablab hay had the highest concentrations of total polyphenols. Mokoboki (2007) reported similar high values of total polyphenols and extracted condensed tannins in lablab hay. Mucuna hay had the highest concentrations of both condensed tannins and hydrolysable tannins. Chikanga-Malunga et al. (2009) reported similarly high concentrations of total tannins in whole mucuna plants at 123 days after planting.

Cowpea hay inclusion increased crude protein intake and digestibility by goats. This result is similar to the findings of Ravhuhali (2010) who reported higher intake responses in goats fed a basal diet of buffalo grass supplemented with cowpea hay. Anelea et al. (2010) also reported increased dry matter and crude protein intakes by goats fed cowpea haulms. The authors attributed this to the high protein content in cowpea hay. In the present study, the level of inclusion for optimal intake was 38.66% of the diet. The optimal intake at this level was calculated to be 500 g per goat per day. This high diet intake may be attributed to the high protein content in cowpea hay. It may, also, be attributed to increases in DM and OM digestibility with increasing levels of cowpea hay inclusion as observed in the present study. In the present study, cowpea inclusion improved nitrogen retention and feed conversion ratio. Nitrogen retention was optimized at 56.25% level of cowpea inclusion, while feed conversion ratio improved linearly with increasing level of cowpea. Live weight of goats also increased linearly with increasing level of cowpea hay inclusion. This linear increase in live weight may be explained in terms of increases in diet intake and digestibility of the legume. This observation has been reported elsewhere in the literature (Savadogo et al., 2000; Ravhuhali, 2010). Cowpea hay inclusion significantly increased blood serum urea. This is similar to the results of Turner et al. (2005) who found increase of urea in the blood serum of goats given *Lespedeza cuneata* or alfalfa (*Medicago sativa*) hays.

Lablab hay inclusion increased diet DM intake and digestibility by goats. The level of inclusion for optimal intake was 32.29% of the diet. The optimal intake at this level was calculated to be 576 g per goat per day. According to Goodchild and McMeniman (1994), animals on supplements with higher protein contents exhibit better intake, digestibility and live weight gain responses. However, lablab inclusion had a negative effect on live weight gain. Weight lost was observed at all inclusion levels. Nsahlai and Umunna (1996) reported no effect on live weight gain of sheep fed a basal diet of oat hay supplemented with lablab. This adverse effect may be explained in terms of the high concentrations of polyphenols in lablab hay. High concentrations of polyphenols in a diet tend to reduce nutrient availability to the animals, thus adversely affecting its live weight gains (Tanner et al., 1990). It was possible that the protein in lablab hay was not available to the animals due to the high tannin content which tend to bind with proteins and hence reducing their digestion (D'Mello, 1992). Similarly, other dietary nutrients such as carbohydrates and vitamins may have been adversely affected by the total polyphenols in the digestive tract, thus negatively affecting nutrient availability and growth at tissue level (Makkar, 2003). Other studies have

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shown that lablab supplement to low quality hay increased average daily gain of ruminants (Ndlovu and Sibanda, 1996; Festus et al., 2008). In the present study, lablab hay inclusion improved nitrogen retention. A low inclusion level of 39.17% optimized nitrogen retention. This observation may be ascribed to high concentrations of total polyphenols in lablab hay. Tannin-protein complexes in an animal's gut are believed to be responsible for low protein digestibility and increased faecal nitrogen concentrations (McNabb et al., 1993).

Mucuna hay inclusion improved diet CP intake and OM digestibility. The results are in agreement with that of Mupangwa et al. (2002). Other studies have shown that mucuna hay is a good crude protein supplement for ruminants fed low quality forages such as maize stover and tropical grass hays (Mupangwa et al., 2002; Nyambati and Sollenberger, 2003). Additionally, mucuna hay inclusion improved feed conversion ratio of the goats. Level of inclusion for optimal live weight change and feed conversion was 42%. Such a level is recommended when performing dose-response trials. Mucuna hay inclusion improved live weight of the animals despite the presence of high levels of tannins in the diet. The improvement in live weight may be explained in terms of increases in diet intake and digestibility by goats. This result is similar to the findings of Brown et al. (2017) who reported higher live weight gains in indigenous Pedi bucks fed tanninferous *Acacia karroo* leaf meal. Solaiman et al. (2010) also reported improved weight gains in goats fed forages high in condensed tannins. Usually, tannins tend to reduce dietary intake and digestibility (Reed, 1995). However, there is evidence that low to moderate tannin content in diet may increase the efficiency of protein utilisation by ruminants (McNabb et al., 1993). Tannins bind with proteins at the rumen pH of 5.5 to 7.0 and protect protein from microbial degradation. These complexes are unstable at low pH in the abomasum, thus the proteins become available for digestion in the small intestines upon appropriate change in pH (McArthur et al., 1992). Mucuna hay significantly increased blood serum urea level. This observation may be ascribed to an increase in diet digestibility. Increased serum urea would, thus, suggest increased absorption of amino acids (Silanikove et al., 1996).

When levels of forage inclusion for optimal intake were used (Experiment 4)**,** goats on cowpea or lablab hays had similar NDF intakes which were higher than those on mucuna hay. Dry matter, OM and NDF intakes per metabolic weight of cowpea hay were higher than those of lablab and mucuna hays. Goats fed lablab hay had the highest final live weight (25.4 kg). Goats fed mucuna hay had better feed conversion ratio than those on cowpea and lablab hay inclusions. However, these values could not be compared due to lack of sufficient information in literature.

Conclusion

All the legumes used in this study had higher protein contents than sorghum hay and thus, have the potential to be utilised as protein supplements, where low quality hay is used as a basal diet for goats. Feed intake, digestibility and final live weights of the goats were optimized at different levels for all the legumes. This may indicate that levels for optimal productivity will depend on the particular parameter of interest. Lablab hay had negative effects on live weight gain of goats. The high concentration of polyphenol in the diet may have exerted adverse effects on the performance of animals. Further studies are required to ascertain this observation.

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DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

REFERENCES

[1] Abule, E., Umunna, N. N., Nsahlai, I. V., Osuji, P. O., Alemu, Y. (1995): The effect of supplementing teff (*Eragrostis tef*) straw with graded levels of cowpea (*Vigna unguiculata*) and lablab (*Lablab purpureus*) hays on degradation, rumen particulate passage and intake by crossbred (Friesian × Boran (zebu)) calves. – Livestock Production Science 44: 221-228.

[2] Adjorlolo, L. K., Amaning-Kwarteng, K., Fianu, F. K. (2001): In vivo digestibility and effect of supplemental mucuna forage on treated rice straw degradation. – Small Ruminant Research 41: 239-245.

[3] Anelea, U. L., Arigbedeb, O. M., Südekuma, K. H., Ikeb, K. A., Onic, A. O., Olaniteb, J. A., Amoleb, G. A., Deleb, P. A., Jolaoshob, A. O. (2010): Effects of processed cowpea (*Vigna unguiculata* L. Walp) haulms as a feed supplement on voluntary intake, utilization and blood profile of West African dwarf sheep fed a basal diet of *Pennisetum purpureum* in the dry season. – Animal Feed Science and Technology 159: 10-17.

[4] AOAC (Association of Official Analytical Chemists) (2005): Official Methods of Analysis, 18th ed. – Association of Official Analytical Chemists, Washington, DC.

[5] Buxton, D. R., Mertens, D. R., Fisher, D. S. (1996): Forage Quality and Ruminant Utilization. – In: Moser, L. E., Buxton, D. R., Casler, M. D. (eds.) Cool-Season Forage Grasses, pp. 229-266. American Society of Agronomy, Madison, WI.

[6] Brown, D., Ng'ambi, J. W. (2017): Effect of polyethylene glycol 4000 supplementation on the performance of yearling male Pedi goats fed dietary mixture levels of *Acacia karroo* leaf meal and *Setaria verticillata* grass hay. – Tropical Animal Health Production 49: 1051-1057.

[7] Brown, D., Ng'ambi, J. W., Norris, D. (2017): Effect of *Acacia karroo* leaf meal inclusion on feed intake, digestibility and live weight gain of Pedi goats fed a *Setaria verticillata* grass hay-based diet. – Journal of Applied Animal Research 46(1): 248-253. http://dx.doi.org/10.1080/09712119.2017.1289939.

[8] Chikanga-Malunga, S. K., Adesogan, A. T., Sollenberger, L. E., Badinga, L. K., Szabo, N. J., Littell, R. C. (2009): Nutritional characterisation of *Mucuna Pruriens*: 1. Effect of maturity on the nutritional quality of botanical fractions and the whole plant. – Animal Feed Science and Technology 148: 34-50.

[9] D'Mello, J. P. F. (1992): Chemical constraints to the use of tropical legumes in animal nutrition. – Animal Feed Science and Technology 38: 237-261.

[10] Festus, T. A., Olaniyi, J. B., Abiodun, A. (2008): Effects of supplementation of *Panicum maximum* with four herbaceous forage legumes on performance, nutrient digestibility and nitrogen balance in West African dwarf goats. – Animal Science Journal 79: 673-679.

[11] Goodchild, A. V., McMeniman, N. P. (1994): Intake and digestibility of low quality roughages when supplemented with leguminous browse. – Journal of Agricultural Science 122: 151-160.

[12] Makkar, H. P. S. (2003): Quantification of Tannins in Tree and Shrub Foliage. – In: Makkar, H. P. S. (ed.) A Laboratory Manual, p. 109. Kluwer Academic Publishers, Dordrecht.

[13] Makkar, H. P. S., Bocowy, N. K., Becker, K., Degen, A. (1995): Some problems in fibre determination of a tannin rich forage (*Acacia saligna* leaves) and their implications in *in vivo* studies. – Animal Feed Science and Technology 55: 67-76.

[14] Matlebyane, M. M., Ng'ambi, J. W., Aregheore, E. M. (2010): Indigenous knowledge (IK) ranking of available browse and grass species and some shrubs used in medicinal and ethno-veterinary practices in ruminant livestock production in Limpopo province, South Africa. – Livestock Research Rural Development 22(3): art. #54.

[15] McArthur, C., Hagerman, A. E., Robbins, C. T. (1992): Physiological Strategies of Mammalian Herbivores against Plant Defences. – In: Palo, R. T., Robbins, C. T. (eds.) Plant Defences Against Mammalian Herbivory, pp. 103-114. CRC Press Inc., Florida.

[16] McDonald, P., Edwards, R. A., Greenhalgh, J. F. D. (2010): Animal Nutrition, 4th ed. – Longman Scientific and Technical, eo-published in U.S.A. with John Wiley and Sons, Inc., New York.
[17] McNabb, W. C., Waghorn, G. C., Barry, T. N., Shelton, I. D. (1993): The effect of condensed tannins in *Lotus pedunculatus* on the digestion and metabolism of methionine, cystine and inorganic sulphur in sheep. – British Journal of Nutrition 70: 647-661.
[18] Mentu, J. N., Owen, E., Abate, A. L., Tanner, J. C. (2001): Botanical and nutritional composition of maize stover, intakes, and feed selection by dairy cattle. – Livestock Production Science 71: 87-96.
[19] Mokoboki, H. (2007): Efficacy of Tannin Assays in Predicting Palatability, Intake, and Digestibility of Leaves of *Acacia* Species Grown in Limpopo Province South Africa. – PhD Thesis, University of Limpopo, Polokwane. South Africa.
[20] Mupangwa, J. F., Ngongoni, N. T., Daka, D. E., Hamudikuwanda, H. (2002): The effect of supplementing a basal diet of veld grass with increasing levels of velvet bean hay (*Mucuna pruriens*) on nutrient parameters in sheep. – Livest Res Rural Dev. 14(4): art. #34.
[21] Ndlovu, L. R., Sibanda, L. M. (1996): Potential of Dolichos lablab (*Lablab purpureus*) and *Acacia tortilis* pods in smallholder goat kid feeding systems in semi-arid areas of Southern Africa. – Small Ruminant Research 21: 273-276.
[22] Nielsen, S., Ohler, T., Mitchell, C. (1997): Cowpea Leaves for Human Consumption: Production, Utilisation and Nutrient Composition. Advances in Cowpea Research, pp. 326-332. – International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultral Sciences (JIRCAS), Ibadan, Nigeria.
[23] Nsahlai, I. V., Umunna, N. N. (1996): Sesbania and lablab supplementation of oat hay basal diet to sheep with or without maize grain. – Animal Feed Science and Technology 61: 275-289.
[24] Nyambati, E. M., Sollenberger, L. E. (2003): Nutritive value of top-canopy herbage of *Mucuna pruriens* and Lablab relay-cropped in maize in the sub-humid highlands of north-western Kenya. – Tropical and Subtropical Agroecosystems 1: 329-343.
[25] Olafadehan, O. A. (2011): Changes in haematological diagnostic parameters of Red Sokoto goats fed tannin-rich *Pterocarpus erinaceus* forage diets. – Veterinarski Arhiv 81: 471-483.
[26] Porter, L. J., Hristich, L. N., Chan, B. G. (1986): The conversion of procyanidins and prodelphinidins to cyanidins and delphinidin. – Phytochemistry 25: 223-230.
[27] Ravhuhali, R. E. (2010): Effect of Cowpea Cultivar Supplementation on Productivity of Pedi Goats and Dorper Sheep Feed *ad libitum* Buffalo Grass. – M.Sc. Dissertation, University of Limpopo.
[28] Reed, J. D. (1995): Nutritional toxicology of tannins and related poly – phenols in forage legumes. – Journal of Animal Science 93: 1516-1528.
[29] Sarwatt, S. V., Laswai, G. H., Ubwe, R. (2003): Evaluation of the potential of *Trichanthera gigantea* as a source of nutrients for rabbit diets under small-holder production system in Tanzania. – Livestock Research Rural Development 15(11): art. #82. http://lrrd.cipav.org.co/lrrd15/11/sarw1511.htm.
[30] SAS (2010): User's Guide: Statistics. – SAS Institute, Inc, Cary, MC.
[31] Savadogo, M., Zemmelink, G., Nianogo, A. J., Van, K. (2000): Cowpea (*Vigna unguiculata* L. Walp) and groundnut (*Arachys hypogea* L.) haulms as supplements to sorghum (*Sorghum bicolor* L. Moench) stover: intake, digestibility and optimum feeding levels. – Animal Feed Science and Technolology 87: 57-69.
[32] Silanikove, N., Gilboa, A., Nir, I., Perevolotsky, A., Nitsan, Z. (1996): Effect of a daily supplement of polyethylene glycol on intake and digestion of tannin-containing leaves (*Quercus calliprinos, Pistacia lentiscus* and *Ceratonia siliqua*) by goats. – Journal of Agricultural Food Chemistry 44: 199-205.

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DOI: http://dx.doi.org/10.15666/aeer/1603_21972212

[33] Solaiman, S., Thomas, J., Dupre, Y., Min, B. R., Gurung, N., Terrill, T. H., Haenlein, G. F. W. (2010): Effect of feeding sericea lespedeza (*Lespedeza cuneata*) on growth performance, blood metabolites, and carcass characteristics of Kiko crossbred male kids. – Small Ruminant Research 93: 149-156.

[34] Tanner, J. C., Reed, J. D., Owen, E. (1990): The nutritive value of fruits (pods and seeds) from four *Acacia* spp. compared with extracted noug (*Guiztia abssinica*) meal as supplements to maize stover for Ethiopian highland sheep. – Animal Production 51: 127-133.

[35] Tolera, A., Merkel, R. C., Goetsch, A. L., Sahlu, T., Negesse, T. (2000): Nutritional Constraints and Future Prospects for Goat Production in East Africa. – In: Merkel, R. C., Adebe, G., Goetsch, A. L. (eds.) The Opportunities and Challenges of Enhancing Goat Production in East Africa, pp. 43-57. Debub University, Awassa, Ethiopia.

[36] Turner, K. E., Wildeus, S., Collins, J. R. (2005): Intake, performance, and blood parameters in young goats offered high forage diets of lezpedeza or alfalfa hay. – Small Ruminant Research 59: 15-23.

[37] Umunna, N. N., Osuji, P. O., Nsahlai, I. V., Khalili, H., Mohamed-Saleem, M. A. (1995): Effect of supplementing oat hay with lablab, sesbania, tagaste or wheat middlings on voluntary intake, N utilisation and weight gain of Ethiopian Menz sheep. – Small Ruminant Research 18: 113-120.

[38] Valley, H., Gowelock, A. H., Bell, M. (1980): Determination of serum Urea Using Diacetyl Monoxime Method. – In: Varley, H. (ed.) Practical Clinical Biochemistry, 5th ed. William Heinemann Medical Books Ltd., London.

[39] Van Soest, P. J., Robertson, J. B., Lewis, B. A. (1991): Methods of dietary fibre, neutral detergent fibre and non-starch monosaccharides in relation to animal nutrition. – Journal of Dairy Science74: 3583-3597.

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DOI: http://dx.doi.org/10.15666/aeer/1603_21972212