Journal of Applied Animal Research

Taylor & Francis
Taylor & Francis Group

Effect of tanniniferous *Acacia karroo* leaf meal inclusion level on feed intake, digestibility and live weight gain of goats fed a *Setaria verticillata* grass hay-based diet

David Brown, Jones W. Ng'ambi & David Norris

Published online: 14 Feb 2017.

Submit your article to this journal

Article views: 1016

View related articles

View Crossmark data

Citing articles: 1 View citing articles

Taylor & Francis
Taylor & Francis Group

🔓 OPEN ACCESS

Effect of tanniniferous *Acacia karroo* leaf meal inclusion level on feed intake, digestibility and live weight gain of goats fed a *Setaria verticillata* grass hay-based diet

David Brown, Jones W. Ng'ambi and David Norris

Department of Agricultural Economics and Animal Production, Faculty of Science and Agriculture, University of Limpopo, Sovenga, South Africa

ABSTRACT

This study aimed to investigate the effects of tanniniferous *Acacia karroo* leaf meal inclusion level on performance of goats fed on a *Setaria verticillata* grass hay-based diet. Twenty indigenous male Pedi goats with an average initial live weight of 17.44 ± 2 kg were allocated, in a completely randomized design, to five dietary treatments containing *Acacia karroo* leaf meal inclusion levels of 20%, 25%, 30%, 40% and 50% of the total diet. Daily dry matter intakes were similar ($P > .05$) across the treatments. *Acacia karroo* leaf meal inclusion improved ($P < .05$) dry matter, organic matter, crude protein, neutral detergent fibre and acid detergent fibre digestibility coefficients. Dietary treatments had no effect on final live weights of goats. However, live weight gains were higher ($P < .05$) in goats fed a diet containing 50% *Acacia karroo* leaf meal inclusion level. Dry matter, crude protein and neutral detergent fibre digestibility coefficients were optimized at *Acacia karroo* leaf meal inclusion levels of 69.4%, 48.3% and 42.7%, respectively. *Acacia karroo* leaf meal inclusion improved nutrient digestibility and live weight gain of the goats and thus has potential to be utilized as a protein supplement when low-quality roughage is used as a basal diet.

1. Introduction

Goats play multiple roles in the livelihood of households of South Africa (Ngambi et al. 2013). They provide benefits in the form of meat, milk, manure, hide and skins, and cash (Peacock 2005). However, the productivity of these goats is constrained by shortage of good-quality feed, especially during the long dry season. Available feed resources during this period are generally deficient in nutrients such as protein, energy, minerals and vitamins, and hence cannot adequately meet the nutritional requirements for maintenance (Manaye et al. 2009). Earlier studies have shown that Pedi goats loss body weight and condition during the dry season (Ravhuhali et al. 2011). There is a need to identify more nutritious feed to alleviate the prevailing nutritional problems of indigenous goats in the communal areas during the dry season.

Browse tree legumes and shrub foliage have been identified as important sources of fodder for livestock in communal rangelands of Southern Africa (Solomon et al. 2008). An important attribute of browse trees is their positive effect on intake and digestibility when supplemented with fibrous basal feeds (Umunna et al. 1995). *Acacia* genus is widely distributed throughout the arid and semi-arid regions of Sub-Saharan Africa, and *Acacia karroo* is the most abundant indigenous tree legume species in Southern Africa (Mapiye et al. 2011). The tree retains its green leaves throughout the year (Barnes et al. 1996) and has potential as a crude protein supplement in ruminant diets. *Acacia karroo* was considered an ecological threat to natural rangelands and tends to be an invasive species (Mapiye et al. 2011). However, research attention has been diverted from its riddance as a weed to its utilization as

a protein supplement for livestock, particularly goats (Mapiye et al. 2011; Brown et al. 2016).

Utilization of *Acacia karroo* leaves is restricted by the presence of secondary plant compounds such as condensed tannins (Mokoboki et al. 2005). High levels of extracted condensed tannins (55–110 g/kg DM) have been reported in *Acacia karroo* leaves (Mokoboki et al. 2005). Intake of condensed tannins by ruminants may depress feed intake and digestibility of diets, and hence adversely affect productivity of the animals (Waghorn 2008). Mixing of shrubs with grass hay-based diets has been hypothesized as an efficient way of diluting the negative effects of undesirable secondary compounds, such as tannins (Bhat et al. 2013). Ondiek et al. (2013) observed higher feed intake, average daily gain and nutrient digestibility in goats fed maize stover supplemented with taninniferous *Acacia tortilis* or *Balanites aegyptiaca* leaf meals. However, the effects of tannin-rich *Acacia karroo* on intake, digestibility and performance of Pedi goats are not available. Additionally, information on the *Acacia karroo* leaf meal inclusion level for optimal productivity of Pedi goats is not available. The aim of this study was, therefore, to determine the effect of *Acacia karroo* leaf meal inclusion level on feed intake, digestibility and live weight gain of Pedi goats fed a *Setaria verticillata* grass hay-based diet.

2. Materials and methods

2.1. Location, experimental diets and feeding

The study was conducted at the University of Limpopo Experimental farm (latitude 27.55°S and longitude 24.77°E) in

October 2014. The ambient temperature at the study site ranges between 20°C and 36°C during summer (November–January) and between 5°C and 25°C during winter (May–July). Fresh leaves of *Acacia karroo* were harvested at the farm in August 2014. The leaves were air-dried in the shade to minimize nutrient losses to ultra violet rays (Dzowela et al. 1995) and then stored in air-tight bags until feeding time. *Setaria verticillata* hay was bought from the local farmer (Fourie Boerdery, Polokwane, Republic of South Africa). The grass and *Acacia karroo* leaves were passed through a hammer mill (13 mm screen) to reduce diet selection by the animals when fed. The chopped forage was thoroughly mixed with *Acacia karroo* leaves according to the dietary treatments in Table 1. The goats were fed *ad libitum*, allowing a 15% refusal of each diet, as suggested by Kaitho et al. (1996). Water was offered *ad libitum* and each goat had access to a mineral lick. There was a preliminary period of 14 days to familiarize the goats with the feeds and research protocol. The goats were individually offered feed once a day at 08:00 h. Feed offered was weighed and recorded daily and feed refusals were weighed every morning before fresh feed was offered. Dry matter values of the feeds and feed refusals were determined. The feeding trial lasted for 21 days, with the last 7 days being for data collection.

2.2. Animals, housing and experimental design

All procedures involving animals were approved by the Animal Research Ethics Committee of the University of Limpopo, South Africa. Twenty yearling male Pedi goats (a local breed in Limpopo province of South Africa) with an average initial body weight of 17.44 ± 2 kg (mean ± SD) were used in the study. Five treatment diets were offered in a completely randomized design with four animals per treatment. The goats were housed in individual holding pens. The pens were installed in a well-ventilated shed with one side open to natural light and roofed to protect goats against the sun and rain. The goats were weighed three times, at the start of the experiment, on the 14th day when data collection commenced and on the 21st day when data collection ended. The weighing of the goats was carried out before morning feeding to avoid feed effect (Sarwatt et al. 2003). All animals were drenched with anthelmintic (Valbazen® broad spectrum dewormer, manufactured by Pfizer Animal NY, USA) and sprayed with Diazintol® (Alfasan international, Holland) before the start of the experiment.

2.3. Digestibility trial

On day 21, the goats were transferred to metabolic crates and each animal was fitted with a faecal bag for *in vivo* digestibility. The goats were adapted for three days to the carrying of faecal collection bag, which was followed by total faecal collection for a period of seven successive days for each animal. Faeces were collected from goats at 08:00 h before feeding. Faeces were weighed daily and subsamples (10% of total weight) were frozen at −20°C for chemical analysis. From the food consumed and faecal matter secreted, apparent digestibility of the nutrients was calculated (McDonald et al. 2011).

2.4. Chemical analysis

The pooled fresh samples of faeces, diets and orts were dried in a forced-air oven at 65°C for 72 h for analyses of DM, OM, CP, ash and fat. DM for all samples was determined by oven-drying at 105°C for 24 h. OM content was determined by combustion of samples at 550°C for 8 h in a muffle furnace according to the methods of AOAC (2002). Nitrogen content of the samples was determined using the Kjeldahl procedure (AOAC 2005). NDF and ADF were measured according to the procedures of Van Soest et al. (1991). Total phenolics were determined using Folin–Ciocalteu methods and expressed as tannic acid equivalent (% DM) (Makkar et al. 1993). Condensed tannins were determined using the Butanol–HCl method and expressed as leucocyanidin equivalent (% DM).

2.5. Statistical analysis

All data on feed intake, *in vivo* digestibility and live weight gain of goats were analysed using the General Linear Model procedures of SAS (SAS 2010). Fisher's least significant difference (LSD) test was applied for mean separation where there were significant differences ($P < .05$). The responses in optimal intake, digestibility and body weight change to the level of browse inclusion were modelled using the following quadratic equation:

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

where Y is the feed intake (g/day), digestibility (coefficient) or body weight change (g/day); a is the intercept; b_1 and b_2 are the coefficients of the quadratic equation; x is the level of inclusion and $-b_1/2b_2$ = level of inclusion value for optimal response. The quadratic model was used because it gave the best fit.

The linear relationships between browse inclusion level and responses in feed intake, digestibility and body weight changes were modelled using the following linear equation:

$$Y = a + bx$$

where Y is the feed intake, digestibility or body weight change; a is the intercept; b is the coefficient of the linear equation; x is the level of inclusion.

3. Results

Nutrient composition and tannin contents of *Acacia karroo* and *Setaria verticillata* leaves are presented in Table 2. *Acacia karroo* had higher crude protein content than *Setaria verticillata* grass hay. However, NDF and ADF contents were higher in *Setaria verticillata* grass hay. *Acacia karroo* contained moderate levels of condensed tannins and total phenolics. Tannins were not detected in *Setaria verticillata* grass hay.

Table 1. Feed composition of the experimental diets.

Diet code	Diet description
$S_{80}A_{20}$	A mixture of 80% *Setaria verticillata* hay and 20% *Acacia karroo* leaves
$S_{75}A_{25}$	A mixture of 75% *Setaria verticillata* hay and 25% *Acacia karroo* leaves
$S_{70}A_{30}$	A mixture of 70% *Setaria verticillata* hay and 30% *Acacia karroo* leaves
$S_{60}A_{40}$	A mixture of 60% *Setaria verticillata* hay and 40% *Acacia karroo* leaves
$S_{50}A_{50}$	A mixture of 50% *Setaria verticillata* hay and 50% *Acacia karroo* leaves

The nutritive values of dietary mixtures of *Setaria verticillata* and *Acacia karroo* are presented in Table 3. There were differences ($p < .05$) in the chemical composition of the dietary mixtures of *Setaria verticillata* and *Acacia karroo* leaves. The OM, CP, fat, condensed tannins and total phenolic contents were higher ($P < .05$) in the diet containing a 50% *Acacia karroo* leaf meal inclusion level, followed by 40%, 30%, 25% and 20% inclusion levels, respectively. The ADF and NDF contents of the diets increased ($P < .05$) as the proportion of *Setaria verticillata* grass hay increased in the diets. All the diets had similar ($P > .05$) ash content values.

The results of the effect of *Acacia karroo* leaf meal inclusion level on feed intake, digestibility and live weight change of Pedi goats fed *Setaria verticillata* grass hay-based diets are presented in Table 4. Daily dry matter intakes were similar ($P > .05$) across the treatments, ranging from 617 to 679 g per goat per day. Similarly, goats consumed the same ($P > .05$) amounts of dietary OM, CP, NDF and ADF contents. Intakes per metabolic weight were similar ($P > .05$) across the diets.

Diet DM, OM, CP, NDF and ADF digestibility values were different ($P < .05$) across the treatments. Diet DM digestibility values were higher ($P < .05$) in goats consuming a diet having a 50% *Acacia karroo* leaf meal inclusion level when compared to diets containing 20%, 25% or 30% *Acacia karroo* leaf meal inclusion levels. Similarly, DM digestibility values were higher ($P < .05$) in goats fed diets having 30% or 40% A*cacia karroo* leaf inclusion levels than those on 20% or 25% inclusion levels. Organic matter digestibility values were higher ($P < .05$) in goats consuming diets containing 40% or 50% *Acacia karroo* leaf meal inclusion levels than those on 20%, 25% or 30% inclusion levels. Goats consuming diets having 30%, 40% or 50% *Acacia karroo* leaf meal inclusion levels had higher ($P < .05$) CP digestibility than those on diets having 20% or 25% inclusion levels. Goats consuming diets containing 25%, 30% or 50% *Acacia karroo* leaf meal inclusion levels had higher ($P < .05$) NDF digestibility values than those of goats on diet with 20% or 40% *Acacia karroo* leaf meal inclusion levels. Acid detergent fibre digestibility was higher ($P < .05$) in goats consuming a diet having 50% *Acacia karroo* leaf meal inclusion level than those on diets having 20%, 25% or 30% inclusion levels.

Goats had similar ($P > .05$) final body weights. However, live weight gains (ADG) were higher ($P < .05$) in goats fed a diet having a 50% *Acacia karroo* leaf meal inclusion level when compared to other treatment groups. Similarly, goats on diets having 30% or 40% *Acacia karroo* leaf meal inclusion levels had higher ($P < .05$) live weight gains than those on diets having 20% or 25% *Acacia karroo* leaf meal inclusion levels.

Dry matter, crude protein and neutral detergent fibre digestibilities were optimized at *Acacia karroo* leaf meal inclusion levels of 69.4%, 48.3% and 42.7%, respectively (Table 5). Organic matter ($r^2 = 0.88$) and acid detergent fibre ($r^2 = 0.92$) digestibilities, and live weight gain ($r^2 = 0.91$) increased linearly with increased inclusion levels of *Acacia karroo* leaves in the diet (Table 6).

4. Discussion

The diets containing 40% and 50% *Acacia karroo* leaf meal inclusion levels provided 9.84% and 10.37% CP contents, respectively. The high CP contents in these diets were due to higher *Acacia karroo* inclusion levels. *Acacia karroo* leaves contain high levels of CP and essential amino acids (Halimani et al. 2002). The CP contents of all the experimental diets were above the minimum level of 8% required for optimal microbial function in the rumen (Norton 2003), suggesting that all the diets could support maintenance requirements and some production levels in ruminants (Van Soest 1994). Leaves of fodder trees have been used as supplements to grass hay-based diets, especially during the critical dry periods of the years (Tshabalala et al. 2013). These tree fodders have been incorporated into the rations of ruminants as substitutes for more expensive processed protein sources (Norton 1994).

The condensed tannin contents of the experimental diets varied from 4.1 g/kg DM for the diet containing a 20% *Acacia karroo* inclusion level to 10.2 g/kg DM for the diet containing 50% *Acacia karroo*. Dube et al. (2001) and Mokoboki et al. (2005) indicated that *Acacia karroo* leaves contain high levels of extracted condensed tannins (CT), ranging from 55 to 110 g/kg DM. It has been reported that CT values above 50 g/kg DM in the diet can produce adverse effects when fed to ruminant animals (Frutos et al. 2004). The CT contents in the experimental diets were below 50 g/kg DM, the level that could be considered detrimental to the animal. According to Ben Salem and Smith (2008), intake of mixed diets is an efficient way of diluting the adverse effects of secondary compounds in plants, such as tannins.

The threshold NDF content beyond which feed intake and digestibility is adversely affected by ruminants is 600 g NDF/

Table 2. Chemical composition (mean ± SD) of the experimental forages.

Nutrient (% DM)	*Acacia karroo* leaves	*Setaria verticillata* hay
Dry matter	97.1 ± 2.01	96.2 ± 0.40
Organic matter	92.1 ± 0.21	91.4 ± 0.12
Crude protein	12.7 ± 2.02	7.9 ± 1.12
Fat	2.4 ± 0.10	0.8 ± 0.01
Ash	7.9 ± 0.40	8.6 ± 0.31
Acid detergent fibre	32.5 ± 3.02	50.7 ± 4.01
Neutral detergent fibre	38.0 ± 4.01	77.9 ± 3.02
Condensed tannins[a]	2.0 ± 0.01	ND
Total Phenolics[b]	1.95 ± 0.001	ND

[a]Condensed tannins as percentage DM leucocyanidin equivalent.
[b]Expressed as tannic acid equivalent (%); ND: Not detected.

Table 3. The nutrient composition of experimental diets (% DM basis).

Nutrient	Treatment					SEM
	$S_{80}A_{20}$	$S_{75}A_{25}$	$S_{70}A_{30}$	$S_{60}A_{40}$	$S_{50}A_{50}$	
Dry matter	95.24[c]	95.86[b]	94.05[e]	95.21[d]	97.01[a]	0.000
Organic matter	91.52[e]	91.56[d]	91.60[c]	91.67[b]	91.75[a]	0.000
Ash	8.47	8.43	8.39	8.32	8.24	0.110
Fat	1.12[e]	1.20[d]	1.28[c]	1.45[b]	1.61[a]	0.041
Crude protein	8.90[e]	9.16[d]	9.34[c]	9.84[b]	10.37[a]	0.132
ADF	47.03[a]	46.12[b]	45.21[c]	43.39[d]	41.57[e]	0.671
NDF	69.90[a]	67.91[b]	65.91[c]	61.93[b]	57.94[e]	0.421
Condensed tannins[#]	0.41[e]	0.51[d]	0.61[c]	0.82[b]	1.02[a]	0.017
Total Phenolics[##]	0.39[e]	0.49[d]	0.58[c]	0.78[b]	0.98[a]	0.003

SEM, Standard error of the means; ADF, Acid detergent fibre; NDF, Neutral detergent fibre; [#], Condensed tannins as percentage DM leucocyanidin equivalent; [##], Expressed as tannic acid equivalent (%).
[a,b,c]: Means in the same row with different superscripts are significantly different ($P < .05$).

Table 4. Effect of different inclusion levels of *Acacia karroo* on diet intake, digestibility and live weight change of Pedi goats fed a basal diet of *Setaria verticillata* hay.

Variable	Treatment					
	$S_{80}A_{20}$	$S_{75}A_{25}$	$S_{70}A_{30}$	$S_{60}A_{40}$	$S_{50}A_{50}$	SEM
Intake (g/goat/day)						
DM	679	633	642	633	617	56.6
OM	621	580	588	581	566	51.9
CP	60	58	60	62	64	5.38
NDF	475	430	423	392	358	36.6
ADF	319	292	290	274	256	25.1
Intake (g/kgW$^{-0.75}$)						
DM	68.2	72.3	69.7	64.8	61.1	6.92
OM	62.4	66.2	63.8	59.4	56.0	6.35
CP	6.07	6.60	6.50	6.30	6.30	0.70
NDF	47.7	49.1	45.9	40.1	34.4	4.20
ADF	32.1	33.3	31.5	28.0	24.6	2.97
Digestibility (coefficient)						
DM	0.57[c]	0.58[c]	0.67[b]	0.72[ab]	0.77[a]	0.024
OM	0.56[b]	0.56[b]	0.57[b]	0.73[a]	0.75[a]	0.030
CP	0.40[b]	0.41[b]	0.55[a]	0.56[a]	0.60[a]	0.042
NDF	0.48[b]	0.63[a]	0.66[a]	0.56[ab]	0.66[a]	0.038
ADF	0.36[b]	0.36[b]	0.37[b]	0.49[ab]	0.61[a]	0.048
Initial LWT (kg)	17.32	18.28	16.52	18.49	16.57	4.841
Final LWT (kg)	17.74	18.77	17.24	19.25	17.83	4.610
ADG (g/goat/day)	20[c]	23[c]	34[b]	36[b]	60[a]	10.37

Note: SEM, Standard error of the means.
[a,b,c], Means with different superscripts in the same row are significantly different ($P < .05$).

kg DM (Meissner & Paulsmeier 1995). The diet containing a 50% *Acacia karroo* inclusion level had 579 g NDF/kg DM, still lower than 600 g NDF/kg DM, indicating its high feeding-value potential. However, Riaz et al. (2014) observed that goats appeared less responsive to increases in dietary fibre fractions (NDF and ADF) than other animal species, and that these feed fractions had a less negative impact on their dry matter intake.

All the experimental goats had similar feed intakes. This might be because all the diets had CP levels above the minimum level of 8% required for optimal ruminal microbial functioning (Norton 2003), and hence optimal diet intake. This result is similar to the findings of Dludla (2010), who reported non-significant differences in total intake when goats were fed *Acacia caffra* and *Euclea crispa* (with high CT concentrations), *Rhus lancea* (with moderate CT concentrations) and *Ziziphus mucronata* (with low CT concentrations). Animut et al. (2008) observed that intakes of DM and OM were similar in goats consuming diets with different levels of condensed tannins from lespedeza. According to Reed (1995) and Frutos et al. (2004), condensed tannin concentration in the diet will depress feed palatability, reduce feed intake and slow down digestion. The reduction in palatability and intake is associated

Table 5. *Acacia karroo* leaf meal inclusion levels for optimal dietary dry matter, crude protein, neutral detergent fibre and acid detergent fibre digestibility (coefficient) in goats on a basal diet of *Setaria verticillata* grass hay.

Factor	Formula	AK level	Optimal Y-level	r^2
DM digestibility	$Y = 0.310 + 0.015x + {}-0.000108x^2$	69.4	0.830	0.96
CP digestibility	$Y = 0.000149 + 0.024x + {}-0.000248x^2$	48.3	0.580	0.88
NDF digestibility	$Y = 0.230 + 0.020x + {}-0.000234x^2$	42.7	0.657	0.35

AK level, *Acacia karroo* leaf meal inclusion level for optimal Y-value.
r^2, Coefficient of determination.

Table 6. Relationships between *Acacia karroo* leaf meal inclusion level (%) and organic matter and acid detergent digestibilities (coefficient) and live weight change (g/goat/day) in male Pedi goats on a basal diet of *Setaria verticillata* grass hay.

Factor	Formula	r^2	Probability
Organic matter digestibility	$Y = 0.436 + 0.0064x$	0.97	.002
ADF digestibility	$Y = 0.671 - 0.000474x$	0.03	.795
Live weight change	$Y = -6.707 + 1.252x$	0.91	.011

r^2: Coefficient of determination.
ADF digestibility: Acid detergent fibre digestibility.

with the astringency in the mouth of the animals (Breslin et al. 1993). A decrease in feed intake has also been reported with higher CT concentration (Bhatta et al. 2002). In the present study, an increase in inclusion of *Acacia karroo* leaf meal in the diet did not adversely affect forage intake of goats.

Diets containing 30%, 40% or 50% *Acacia karroo* leaf meal inclusion levels improved crude protein digestibility, despite the relatively higher tannin contents. *Acacia karroo* leaf meal inclusion level of 48.3% optimized crude protein digestibility. *Acacia karroo* leaf meal inclusion increased ruminal protein levels, resulting in improved conditions for microbial growth and multiplication (Makkar 2003). Increased microbial population results in higher digestibility and intake of the diet. The nutritional benefit of CT in ruminant's diet is also due primarily to the protection of plant proteins from microbial degradation in the rumen and the resultant increase in protein flow to the intestines (Waghorn et al. 1994; McNabb et al. 1996). Tannins in forages may enhance protein utilization and improve amino acid absorption in ruminants (Waghorn et al. 1987). These reports support the findings in the present study. Makkar (2003) observed that tannins bind with proteins at pH of 5.5–7.0, thereby slowing down microbial degradation of the proteins. The slower rate of microbial protein digestion in the rumen prevents nitrogen loss as urea, facilitating the absorption of amino acids in the small intestines, and improving overall nitrogen utilization (Mueller-Harvey 2006). It has also been documented that condensed tannins exert their inhibitory effect on protein degradation in the rumen by protecting plant protein from cleavage by proteases or directly inhibiting the proteases themselves (Aerts et al. 1999). The precise mechanism by which tannins reduce ruminal protein digestion and hence improve its overall utilization merits further study.

Diets containing a 50% *Acacia karroo* leaf meal inclusion level improved fibre digestibility. However, the level of inclusion for optimal NDF digestibility was 42.7%. Usually, tannins tend to reduce fibre digestibility by binding bacterial enzymes and forming indigestible complexes with carbohydrates, particularly hemicellulose, cellulose, starch and pectins, thus, rendering these nutrients inaccessible to microorganisms (Schofield et al. 2001). However, the present results indicate that fibre degradation in the rumen can be increased in animals consuming forage tannins. Waghorn et al. (1987), also, reported a 13% increase in fibre digestion in the rumen of sheep consuming *Lotus pedunculatus* containing 5.5% CT.

The increase in the inclusion level of *Acacia karroo* leaf meal resulted in increased daily weight gains of the goats. A significantly higher average daily gain was observed in goats consuming a diet with a 50% *Acacia karroo* leaf meal inclusion level. This might have been due to increase in diet digestibility with an

increase in *Acacia karroo* inclusion level. Ash and Norton (1987) observed that body weight gain in goats is sensitive to protein and energy contents of the diet consumed. The improvement in body weight gain of Pedi goats might, also, be associated with improved protein utilization by goats on diets with higher *Acacia karroo* inclusion levels (Solaiman et al. 2010). This result is similar to the findings of Gwanzura (2011), who reported higher body weight gains in Pedi goats fed taninniferous Mucuna hay. Forages containing from 20 to 40 g of CT kg^{-1} DM increase rumen escape value of herbage (Terril et al. 1992) and enhance weight gains in ruminants (Turner et al. 2005). Other authors have reported improved weight gain in goats and lambs fed forages high in CT (Douglass et al. 1995; Solaiman et al. 2010). Results of Njidda and Ikhimioya (2010) with tannin-rich plants revealed that some rumen microorganisms are able to metabolize tannins or remain active in a high tannin environment and overcome their detrimental effects, which in turn improves animal performance. Higher concentrations of total polyphenols in a diet tend to reduce nutrient availability to the animals, thus adversely affecting their body weight gains (Tanner et al. 1990). However, in the present study, the high total polyphenolic content present in the diets having a 50% *Acacia karroo* inclusion level diet did not adversely affect the live weight of the goats.

5. Conclusion

Inclusion of *Acacia karroo* leaves improved nutrient digestibility and growth rate of goats. Dry matter, crude protein and neutral detergent fibre digestibilities were optimized at different *Acacia karroo* leaf meal inclusion levels of 69.4%, 48.3% and 42.7%, respectively. This may indicate that levels for optimal productivity will depend on the particular parameter in question. *Acacia karroo* leaf meal, therefore, has the potential of being utilized as a protein feed during the dry season when goats depend on low-quality roughages.

Funding

References

Aerts RJ, Barry TN, McNabb WC. 1999. Polyphenols and agriculture: beneficial effects of proanthocyanidins in forages. Agric Ecosyst Environ. 75:1–12.

Animut G, Puchala R, Goetsch AL, Patra AK, Sahlu T, Varel VH, Wells J. 2008. Methane emission by goats consuming diets with different levels of condensed tannins from lespedeza. Anim Feed Sci Tech. 144:212–227.

AOAC. 2002. Official methods of analysis. 16th ed. Washington, DC: Association of Official Analytical Chemists.

AOAC. 2005. Official methods of analysis. 18th ed. Washington, DC: Association of Official Analytical Chemists.

Ash A, Norton BW. 1987. Studies with the Australian cashmere goat. I. Growth and digestion in male and female goats given pelleted diets varying in protein content and energy level. Aust J Agric Res. doi:10.1071/AR9870957.

Barnes RD, Filer DL, Milton SJ. 1996. *Acacia karroo*: monograph and annotated bibliography. Tropical Forestry Papers, Oxford Forestry Institute, Oxford, UK.

Ben Salem H, Smith T. 2008. Feeding strategies to increase small ruminant production in dry environments. Small Ruminant Res. 77:174–194.

Bhat TK, Kannan A, Singh B, Sharma OP. 2013. Value addition of feed and fodder by alleviating the anti-nutritional effects of tannins. Agric Res. 2:189–206.

Bhatta R, Shinde AK, Vaithiyanathan S, Sankhyan SK, Verma DL. 2002. Effect of polyethylene glycol-6000 on nutrient intake, digestion and growth of kids browsing *Prosopis cineraria*. Anim Feed Sci Technol. 101:45–54.

Breslin PAS, Gilmore MM, Beauchamp GK, Green BG. 1993. Psychophysical evidence that oral astringency is a tactile sensation. Chem Senses. 18:405–417.

Brown D, Ng'ambi JW, Norris D. 2016. Voluntary intake and palatability indices of Pedi goats fed different levels of *Acacia karroo* leaf meal by cafeteria method. Indian J Anim Res. 50:41–47.

Dludla SP. 2010. The effect of condensed tannins on goats' body weight [dissertation]. Department of Agriculture, Faculty of Science and Agriculture, University of Zululand.

Douglass GB, Wang Y, Waghorn GC, Berry TN, Purchas RW, Foote AG, Wilson GF. 1995. Live weight gain and wool production of sheep grazing *Lotus corniculatus* and Lucerne (*Medicago sativa*). New Zealand J Agric Res. 38: 95–104.

Dube JS, Reed JD, Ndlovu LR. 2001. Proanthocyanidins and other phenolics in *Acacia* leaves of Southern Africa. Anim Feed Sci Technol. 91:59–67.

Dzowela BH, Hove L, Mafongoya PL. 1995. Effect of drying method on chemical composition and in vitro digestibility of multi-purpose tree and shrub fodders. Trop Grasslands. 29:263–269.

Frutos P, Hervás G, Giráldez FJ, Mantecón AR. 2004. Tannins and ruminant nutrition: Review. Span J Agric Res. 2:191–202.

Gwanzura T. 2011. Evaluation of mixtures of forage sorghum and selected legumes for Pedi goat production in Limpopo province [PhD thesis]. Department of Animal Production, University of Limpopo.

Halimani TE, Ndlovu LR, Dzama K, Chimonyo M, Miller BG. 2002. Growth performance of pigs fed on diets containing *Acacia karroo*, *Acacia nilotica* and *Colophospermum mopane* leaf meals. Livestock Research for Rural Development. Volume 19, Article #187. November 20, 2015. Available from: http://www.lrrd.org/lrrd19/12/hali19187.htm.

Kaitho RJ, Umunna NN, Nsahlai IV, Tamminga S, Van Bruchem J, Hanson J, Van De Wouw M. 1996. Palatability of multipurpose tree species: effect of species and length of study on intake and relative palatability by sheep. Agrofor Syst. 33:249–261.

Makkar HPS. 2003. Effects and fate of tannins in ruminant animals, adaptation to tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. Small Ruminant Res. 49:241–256.

Makkar HPS, Bluemmel M, Borowy NK, Becker K. 1993. Gravimetric determination of tannins and their correlations with chemical and protein precipitation methods. J. Sci Food Agric. 61:161–165.

Manaye T, Tolera A, Zewdu T. 2009. Feed intake, digestibility and body weight gain of sheep fed Napier grass mixed with different levels of *Sesbania sesban*. Livest Sci. 122:24–29.

Mapiye C, Chimonyo M, Marufu MC, Dzama K. 2011. Utility of *Acacia karroo* for beef production in Southern African smallholder farming systems: a review. Anim Feed Sci Technol. 164:135–146.

McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA, Sinclair LA, Wilkinson RG. 2011. Animal nutrition. 7th ed. London: Prentice Hall.

McNabb WC, Waghorn GC, Peters JS, Barry TN. 1996. The effect of condensed tannins in Lotus pedunculatus on the solubilisation and degradation of ribulose-1, 5-bisphosphate carboxylase (EC 4.1.1.39; Rubisco) protein in the rumen and sites of Rubisco digestion. Br J Nutr. 76:535–549.

Meissner HH, Paulsmeier DV. 1995. Plant compositional constituents affecting between-plant and animal species prediction of forage intake. J Anim Sci. 73:2447–2457.

Mokoboki HK, Ndlovu LR, Ngambi JW, Malatje MM, Nikolovav RV. 2005. Nutritive value of Acacia tree foliages growing in the Limpopo province of South Africa. S Afr J Anim Sci. 35:221–228.

Mueller-Harvey I. 2006. Unravelling the conundrum of tannins in animal nutrition and health. J. Sci Food Agr. 86:2010–2037.

Ngambi JW, Alabi OJ, Norris D. 2013. Role of goats in food security, poverty alleviation and prosperity with special reference to Sub-Saharan Africa: a review. Indian J Anim Res. 47:1–9.

Njidda AA, Ikhimioya I. 2010. Nutritional evaluation of some semi-arid browse forages leaves as feed for goats. Eur J Appl Sci. 2:108–115.

Norton BW. 1994. Tree Legumes as dietary supplements for ruminants. In: Gutteridge RC, Shelton HM, editors. Forage Tree Legumes in Tropical Agriculture. CAB International; p. 192–201.

Norton BW. 2003. The nutritive value of tree legumes. In: Gutteridge RG, Shelton HM, editors. Forage Tree Legumes in Tropical Agriculture. Available from: http://www.fao.org/ag/AGP/AGPC/doc/Publicat/Gutt-shel/x5556e0j.htm#4.1.

Ondiek JO, Ogore PB, Shakala EK, Kaburu GM. 2013. Feed intake, digestibility and performance of growing small East African goats offered maize (*Zea mays*) stover supplemented with *Balanites aegyptiaca* and *Acacia tortilis* leaf forages. Basic Res J Agric Sci Rev. 2:21–26.

Peacock C. 2005. Goats – a pathway out of poverty. Small Ruminant Res. 60:179–186.

Ravhuhali KE, Ng'ambi JW, Norris D, Ayodele VI. 2011. The feeding value of four Cowpea Hay cultivars and effect of their supplementation on intake and digestibility of buffalo grass hay fed to pedi goats. Asian J Anim Vet Adv. 6:909–922.

Reed JD. 1995. Nutritional toxicology of tannins and related polyphenols in forage legumes. J Anim Sci. 73:1516–1528.

Riaz MQ, Südekum KH, Clauss M, Jayanegara A. 2014. Voluntary feed intake and digestibility of four domestic ruminant species as influenced by dietary constituents: a meta-analysis. Livest Sci. 162:76–85.

SAS. 2010. User's guide: statistics. Cary, MC: SAS Institute.

Sarwatt SV, Laswai GH, Ubwe R. 2003. Evaluation of Trichanthera gigantea as a source of nutrients for rabbit diets under smallholder production system in Tanzania. Livest Res Rural Dev. 15: 24–34.

Schofield P, Mbugua DM, Pell AN. 2001. Analysis of condensed tannins: a review. Anim Feed Sci Technol. 91:21–40.

Solaiman S, Thomas J, Dupre Y, Min BR, Gurung N, Terrill TH, Haenlein GFW. 2010. Effect of feeding sericea lespedeza (*Lespedeza cuneata*) on growth performance, blood metabolites, and carcass characteristics of Kiko crossbred male kids. Small Rumin Res. 93:149–156.

Solomon T, Dlamini BJ, Dlamini AM. 2008. Dynamics of Savannas in Swaziland: encroachment of woody plants in relation to land use and soil classes and indigenous knowledge on plants utilization. Res J Bot. 3:49–64.

Tanner JC, Reed JD, Owen E. 1990. The nutritive value of fruits (pods with seeds) from four *Acacia* spp. compared with noug (*Guizotia abyssinica*) meal as supplements to maize stover for Ethiopian highland sheep. Anim Prod. 51:127–133.

Terril TH, Rowan AM, Douglas GB, Barry TN. 1992. Determination of extractable and bound condensed tannin concentrations in forage plants, protein concentrates meals and cereal grains. J Sci Food Agric. 58:321–329.

Tshabalala T, Sikosana JLN, Chivandi E. 2013. Nutrient intake, digestibility and nitrogen retention in indigenous goats fed on *Acacia nilotica* fruits treated for condensed tannins. S Afr J Anim Sci. 43:457–463.

Turner KE, Wildeus S, Collins JR. 2005. Intake, performance, and blood parameters in young goats offered high forage diets of lespedeza or alfalfa hay. Small Ruminant Res. 59:15–23.

Umunna N, Osuji PO, Khalili H, Nsahlai IV, Crosse S. 1995. Comparative feeding value of forages from two cereal-legume based cropping systems for beef production from cross breed (*Bos taurus* x *Bos indicus*) steers and subsequent performance of underfed and realimented steers. J Anim Sci. 61:35–42.

Van Soest PJ. 1994. Nutritional ecology of the ruminants. 2nd ed. New York: Cornell University Press. ISBN: 9780801427725, pp 476.

Van Soest PJ, Robertson JB, Lewis BA. 1991. Methods for dietary fibre, neutral detergent fibre and non-starch polysaccharide (NSP) in relation to animal nutrition. J Dairy Sci. 74:3583–3597.

Waghorn G. 2008. Beneficial and detrimental effects of dietary condensed tannins for sustainable sheep and goat production-progress and challenges. Anim Feed Sci. Technol. 147:116–139.

Waghorn GC, Ulyatt MJ, John A, Fisher MT. 1987. The effect of condensed tannins on the site of digestion of amino acids and other nutrients in sheep fed on Lotus comiculatus L. Br J Nutr. 57:115–126.

Waghorn GC, Shelton ID, McNabb WC, McCutcheon SN. 1994. Effects of condensed tannins in Lotus pedunculatus on its nutritive value for sheep. 2. Nitrogenous aspects. J. Agr Sci. 123:109–119.