EFFECTS OF DIETARY *VACHELIA KARROO* LEAF MEAL INCLUSION ON MEAT QUALITY AND HISTOLOGICAL PARAMETERS IN PEDI BUCKS FED A *SETARIA VERTICILLATA* HAY-BASED DIET

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(Received 1st Nov 2018; accepted 20th Dec 2018)

Abstract. The objective of this study was to investigate the effect of dietary *Vachellia karroo* leaf meal inclusion on growth performance, meat quality and histological parameters in bucks**.** A total of thirty yearling Pedi bucks with a mean initial body weight of 16.7 ± 3.3 kg were randomly assigned to five treatments in a completely randomized design. *Vachellia karroo* leaf meal inclusion levels of 20, 25, 30, 40 and 50% were fed to the animals for 60 days. The results showed that dietary treatments had no effect on the final live weights and average daily gains of bucks. Similarly, yields of different carcass components and meat sensory attributes were not affected by the *V. karroo*. Bucks fed 25% *V. karroo* leaf meal had higher meat L* values than those on diets 30 or 40% inclusion levels. The livers of bucks fed 20, 25 or 30% *V. karroo* leaf meal were not adversely affected. However, severe hepatocyte degeneration was noticed in the liver tissues of bucks fed 40 or 50% leaf meal. Dietary *V. karroo* did not cause any serious damage to the kidneys of the bucks. Thus, *V. karroo* leaf meal inclusion levels of 20 to 30% are recommended.
Keywords: *goats, tannin, carcass characteristics, sensory evaluation, acacia*

Introduction

Pedi goats in communal areas of Limpopo province, South Africa depend on *Vachellia karroo* (*Acacia karroo*) leaves, particularly during the dry season (Jamala et al., 2013). *Vachellia karroo* leaves contain high levels of extracted condensed tannins ranging from 55 – 110 g/kg DM and have potent antioxidant properties (Mokoboki et al., 2005; Moon et al., 2014). Antioxidant activity of these plants is attributed to their phenolic compound content (Velasco and Salinas, 2011). Antioxidant activity of plant extracts such as condensed tannins have positive effect on meat quality and oxidative stability (Moyo et al., 2012; Qwele et al., 2013). On the other hand, high condensed tannin contents in the diet negatively affect nutrient availability (Gxasheka et al., 2015). Reports on the effects of tanniferous diets on small ruminant productivity and meat quality are not conclusive. Some authors found that tannin-rich diets positively influence chevon quality (Priolo and Vasta, 2007; Mapiye et al., 2009; Marume, 2010; Bakare and Chimonyo, 2011; Ngambu et al., 2012, 2013), whereas, others found no clear evidence (Mapiye et al., 2010). Additionally, *Vachellia karroo* leaf meal inclusion levels for optimum Pedi bucks meat quality were not found in the literature.

Kidney and liver are vital organs in the animal's body and play vital role in the detoxification process. Dysfunction in liver and kidney may lead to diseases such as ascites and uremia (Karimi et al., 2014). Ruminants browsing on tanniferous forage have adapted rumen micro-organisms that detoxify many, but not all plant secondary

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1702_28932909

metabolites (Cheeke, 1988). A large intake of tannins in the diet may cause kidney irritation and liver damage due to the detoxification process as a consequence of increased enzymatic demand (Van Soest, 1994; Mahgoub et al., 2008). Previous studies have reported a negative effect of condensed tannins on the histopathology of Boer goats (Mbatha et al., 2002). According to the authors, increased dietary tannin levels induced thickening and/or keratinization of epithelial tissue in the reticulum, rumen, omasum and abomasum. Increased tannin levels also resulted in a loss of epithelial cells, erosion of microvilli and shortened villi height in the duodenum (Mbatha et al., 2002). Karimi et al. (2014) reported histological changes in the kidney and liver parenchyma of GhezelxArkhar Merino crossbred lambs fed low tannin sorghum grain. Goats are predominantly browsers and they are able to consume large amounts of tannin-rich forage, which may increase the risk of exposure to sub-clinical systemic toxicity (Gilboa, 1995). Hence, monitoring of these organs in nutritional studies is imperative. There is paucity of information on the effect of tanniferous diets on the liver and kidney of goats. It is hypothesized that increased dietary tannin may result in variable damage of these organs. This study investigated the effects of *Vachellia karroo* leaf meal inclusion on meat quality and histology of livers and kidneys of Pedi bucks.

Materials and methods

Study site

The study was conducted at the University of Limpopo Experimental farm, South Africa (latitude 27.55° S and longitude 24.77° E). The ambient temperatures at the study site range between 20 and 36 °C during summer and between 5 and 25 °C during winter. Mean annual rainfall is 446.8 mm with the dry season occurring between April and October and the rainy season occurring between November and March.

Collection, drying and storage of plant material

Vachellia karroo leaves were harvested during the summer months (November-January). Branches of each shrub were removed manually and placed in a shed. Leaves were allowed to air dry on the branches and then removed by carefully beating the branches with sticks. The leaves were stored in air-tight bags until feeding time. Detailed reviews on the botanical description of *V. karroo* have been described by Barnes et al. (1996). *Setaria verticillata* (L.) P. Beauv. is a perennial grass belonging to the tribe Panacea and is widely grown by commercial farmers in Limpopo Province of South Africa. The grass is well grazed during summer and is suitable for hay making. Botanical authentication of the plant materials was done at the Larry Leach Herbarium, Department of Biodiversity, University of Limpopo.

Animal, management, diet and experimental design

All animal procedures were approved by the Animal Research Ethics Committee of the University of Limpopo, South Africa. A total of thirty yearling Pedi bucks (*Capra hircus*), (a local indigenous breed in Limpopo province of South Africa) with a mean initial body weight of 16.7 ± 3.3 kg were randomly assigned to five treatments in a completely randomized design. Each treatment had three replicates with two goats per replicate. The animals were housed in individual holding pens (1 × 3 m^2) that were installed in a well ventilated shed with one side open to natural light and roofed to

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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protect animals against the sun and rain. Yearling Pedi bucks were selected because they are the ones fattened for meat in the province. All animals were drenched with an anthelmintic (Valbazen® broad spectrum dewormer, manufactured by Pfizer Animal NY, USA) and sprayed with Diazintol® (Alfasan International, Holland) before the start of the experiment.. The goats were individually fed ad libitum once a day at 8:00 am, allowing a 15% refusal of each diet (Kaitho et al., 1996) and they had free access to clean water and a salt block. Prior to the trial, the animals were given the dietary treatment for 14 d ad libitum for adaptation, and the feeding trial lasted for 60 d. The grass and *V. karroo* leaves were chopped and thoroughly mixed to avoid diet selection by the animals when fed (*Table 1*). *Vachellia karroo* leaf meal inclusion levels of 20, 25, 30, 40 and 50 were used in the present study. These inclusions include low and high tannin levels as indicated in the literature (Brown et al., 2017). Feed intake was recorded on a daily basis. Intake was calculated by subtracting leftovers from the feed given. Dry matter values of the feeds and feed refusals were determined. The goats were weighed three times, at the start of the experiment, on day 54 and on the 60th day when data collection ended. Goats were weighed before morning feeding to avoid feed effect. Average daily gains were calculated as differences between final and initial body weights divided by number of feeding days.

Table 1. *Feed composition of the experimental diets*

Diets		
Diet code	***Vachellia karroo* (%)**	***Setaria verticillata* hay (%)**
$V_{20}S_{80}$	20	80
$V_{25}S_{75}$	25	75
$V_{30}S_{70}$	30	70
$V_{40}S_{60}$	40	60
$V_{50}S_{50}$	50	50

Nutrient composition of *V. Karroo* and *S. verticillata* grass was previously reported by Brown and Ng'ambi (2017). The same applies to the nutritive values of dietary mixtures of the browse and grass hay used in the present study (*Tables 2* and *3*).

Table 2. *Nutrient composition of Vachellia karroo leaves and Setaria verticilllata hay*

Nutrient	***Vachellia karroo***	***Setaria verticillata hay***
Dry matter (g/kg)	971	962
Organic matter (g/kg DM)	921	914
Crude protein (g/kg DM)	127	79
Acid detergent fibre (g/kg DM)	325	507
Neutral detergent fibre (g/kg DM)	380	779
Condensed tannins (%DM)[1]	2.0	0
Total phenols (%DM)[2]	1.9	0

[1]Condensed tannins as percentage DM leucocyanidin equivalent
[2]Expressed as tannic acid equivalent (%)

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1702_28932909

Table 3. *Chemical composition of the dietary mixtures of Vachellia karroo leaves and Setaria verticillata grass hay*

	Diet				
Nutrient	**$V_{20}S_{80}$**	**$V_{25}S_{75}$**	**$V_{30}S_{70}$**	**$V_{40}S_{60}$**	**$V_{50}S_{50}$**
Dry matter (g/kg)	952	958	940	952	970
Organic matter (g/kg DM)	915	915	916	916	917
Crude protein (g/kg DM)	89	91	93	98	103
Acid detergent fibre (g/kg DM)	470	461	452	433	415
Neutral detergent fibre (g/kg DM)	699	679	659	613	579
Condensed tannins (%DM)[1]	0.4	0.5	0.6	0.8	1.0
Total phenols (%DM)[2]	0.3	0.4	0.5	0.7	0.9

[1]Condensed tannins as percentage DM leucocyanidin equivalent
[2]Expressed as tannic acid equivalent (%)

Slaughter and carcass evaluation

Prior to slaughter and muscle sample collection, the goats were fasted for 16 h with free access to drinking water and their body weight was recorded immediately after fasting. The animals were slaughtered humanely in the abattoir facility at the University Experimental Farm. The weights of the hot carcass and internal organs were recorded. The gastro-intestinal (GI) tract, including alimentary canal, reticulo-rumen and intestines were weighed after the removal of ruminal contents. Carcasses were chilled at 4 °C for 24 h. After this period, cold carcass weight (CCW) was determined.

Meat quality determination

The pH value at 1 h in *Longissimus thoracic et lumborum* muscle was measured after evisceration by using a pH meter equipped with a penetrating electrode (Crison pH25, CRISON instruments S. A., Alella, Spain). Before measurement, pH meter was calibrated with standard pH buffer (pH 4.0, 7.0 and 10.0). At 24 h postmortem, the entire *Longissimus thoracic et lumborum* was removed for pH, meat color and cooking loss. Meat color (L* = lightness, a* = redness and b* = yellowness) was measured using a spectrophotometer with a D-65 illuminant and an aperture size of 50 mm (45/0 BYK-Gardener instrument GmbH, Germany). Before measurement, the spectrophotometer was calibrated with a white tile (model CR-A43). Three readings were taken by rotating the instrument 90° between measurements, in order to obtain a representative average value of the color, and avoiding connective tissues and intramuscular fat. The readings were taken 1 and 24 h post-mortem. The meats were allowed to bloom for 1 h prior to color analysis.

For cooking loss analysis, blocks of *longissimus thoracic et lumborum* muscle, measuring approximately 7 × 4 × 4 cm, were used to determine cooking loss (Babikerm et al., 1990) and shear force values (Chrystall et al., 1994). The muscle was weighed, placed in a water tight PVC plastic bag and cooked in a water bath at 85 °C for 45 min, until an internal temperature of 70 °C was attained. The samples were cooled and re-weighed. Cooking loss (CL) was calculated using the following

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formula: Cooking loss % = [(weight before cooking – weight after cooking) / weight before cooking] × 100 as described by Ding et al. (2010). After measurement of cooking loss, cooked samples were used to determine meat Warner Bratzler shear force. Three sub-samples (cut parallel to the muscle fibers with a cross-section of 1 × 1 cm and at least 3 cm long) were removed from each cooked muscle. The sub-samples were sheared perpendicular to the fiber direction with an Instron Universal Testing Machine (Model 3344, Instron Industrial Products, GC, USA) equipped with a Warner-Bratzler (WB) shear force apparatus (crosshead speed at 400 mm/min, one shear in the center of each core). The measurements were read in Newton. Dressing percentage was calculated as the ratio of hot carcass weight divided by slaughter body weight and the result multiplied by 100. Water holding capacity (WHC) of the meat was measured as the amount of water expressed from a fresh meat sample (1 g) held under pressure (60 kg) using the filter-paper press method (Trout, 1988).

Meat sensory evaluation

Meat samples used for consumer sensory evaluation were obtained from each carcass and were cut 24 h post-slaughter. The meat samples were cut into cubes (2 × 2 cm), which were placed in watertight PVC plastic bags and cooked in a boiling water bath at a temperature of 85 °C for 45 min (Babikerm et al., 1990). Salt was added to taste. Twenty trained consumer panelists from the University of Limpopo were used for the consumer sensory assessment of meat. Panelists were screened and selected following guidelines from Cross et al. (1978). The panelists were taught how to infer and record scores for each variable. The waiting period between meat sample tastings was 10 min. Distilled water was served to panelists to freshen their mouths between sub-sample assessments to avoid crossover effects. Five-point descriptive scales were used to evaluate the sensory attributes (*Table 4*).

Table 4. *Evaluation scores used by the sensory panel*

	Sensory attribute					
Score	**Tenderness**	**Juiciness**	**Flavor**	**Taste**	**Aroma**	**Overall acceptability**
1	Too tough	Too dry	Very bad flavor	Dislike extremely	Dislike extremely	Dislike extremely
2	Tough	Dry	Poor flavor	Dislike	Dislike	Dislike
3	Neither tough nor tender	Neither dry nor juicy	Neither bad nor good	Neither like nor dislike	Neither like nor dislike	Neither like nor dislike
4	Tender	Juicy	Good flavor	Like	Like	Like
5	Extremely tender	Extremely juicy	Very good flavor	Like extremely	Like extremely	Like extremely

Histological analysis

Liver and kidney samples from each goat were collected and preserved in 10% neutral buffered formalin for 24 h. Subsequently, liver and kidney tissues were dehydrated using standard histological techniques in graded ethanol series and embedded in paraffin wax for histopathology examination (Sanchez-Chardi et al., 2008). From each sample, 60-65 μm sections were cut and mounted on glass slides

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1702_28932909

before staining with haematoxylin and eosin. Slides were examined under light trinocular microscopy at 400X (Leica Microsystems model DM750, Leica, Bannockburn, IL, USA). Each slide was photographed with a DVC digital camera (Digital Video Camera Company, Austin, TX) mounted on a BH-2. The process was as described by Sanchez-Chardi et al. (2009).

Chemical analysis

Dry matter, organic matter and crude protein were determined using the methods described by AOAC (2005). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by the method of Van Soest (1994). Total phenolics were determined using Folin-Ciocalteau methods and expressed as tannic acid equivalent (% DM) (Water and Mole, 1994). Condensed tannins were determined using the Butanol-HCl method and expressed as leucocyanidin equivalent (%DM) (Porter et al., 1986). For each measurement, duplicate analyses were done.

Statistical analysis

Statistical analysis was performed using the GLM procedure of SAS (SAS, 2010). Initial live weight was fitted as covariate for carcass traits. The data are expressed as the mean ± SEM and analyzed using one-way analysis of variance (ANOVA). Fisher's Protected Least Significant Difference (LSD) test was used for the post hoc analyses. A $P < 0.05$ was considered statistically significant for all data.

Results

Nutrient composition of Vachellia karroo and Seteria verticillata grass hay

Vachellia karroo contained 127 g CP/kg DM and 921 g OM/kg DM. It also contained phenolic compounds. *Seteria verticillata* grass hay contained 79, 779 and 507 g of CP, NDF and ADF/kg DM, respectively. *Setaria verticillata* hay has no traces of phenolic compounds (*Table 2*). The nutritive values of dietary mixtures of *V. karroo* and *S. verticillata* hay are presented in *Table 3*. Diet containing 50% *V. karroo* leaf meal contained 103 g CP/kg DM. The condensed tannin and total phenolic contents were 1.0 and 0.9%, respectively. A diet containing 20% *V. karroo* leaf meal inclusion had 89 g CP/kg DM, 0.4% condensed tannin and 0.3% total phenolic content.

Feed intake and growth performance

Daily dry matter intakes were similar ($P > 0.05$) across the dietary treatments, ranging from 638 to 786 g per goat. Similarly, goats consumed the same ($P > 0.05$) daily amounts of organic matter (OM), crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents. *Vachellia karroo* inclusion did not ($P > 0.05$) affect the final body weights and average daily gains of goats (*Table 5*).

Slaughter performance and internal organ weight of bucks

As shown in *Table 6*, dietary *V. karroo* leaf meal inclusion had no effect ($P > 0.05$) on hot and cold carcass weights of bucks. Similarly, the internal organ weights of bucks were not affected ($P > 0.05$) by the dietary treatments.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1702_28932909

Table 5. *Effect of Vachellia karroo leaf meal inclusion level on diet intake and growth performance of yearling Pedi bucks fed a Setaria verticillata grass hay-based diet*

Variable	Treatment					SEM	*P* value
	$V_{20}S_{80}$	$V_{25}S_{75}$	$V_{30}S_{70}$	$V_{40}S_{60}$	$V_{50}S_{50}$		
Intake (g/goat/day)							
Dry matter	752	786	638	661	686	70.3	0.526
Organic matter	688	720	585	606	630	64.5	0.531
Crude protein	66	72	59	64	70	6.83	0.647
NDF	525	533	421	409	397	45.9	0.135
ADF	353	362	288	286	285	31.5	0.232
Initial body weight (kg)	16.0	17.3	13.7	16.1	15.2	2.55	0.815
Final body weight (kg)	22.8	24.1	21.4	23.8	24.6	2.61	0.800
Average daily gain (g)	113	114	129	129	157	23.8	0.204

SEM: Standard error of the means; NDF: Neutral detergent fiber; ADF: Acid detergent fiber

Table 6. *Effects of Vachellia karroo leaf meal inclusion level on slaughter performance and internal organ weight of bucks fed a Setaria verticillata grass hay-based diet*

Variable	Treatment					SEM	*P* value
	$V_{20}S_{80}$	$V_{25}S_{75}$	$V_{30}S_{70}$	$V_{40}S_{60}$	$V_{50}S_{50}$		
Pre-slaughter weight (kg)	22.8	24.1	21.4	23.8	24.6	1.61	0.686
Hot carcass weight (kg)	7.8	8.3	6.9	8.2	8.9	0.64	0.361
Cold carcass weight (kg)	7.4	7.8	6.1	7.1	8.0	0.57	0.196
Head (g)	1882.3	1888.9	1772.8	1706.8	1987.3	141.8	0.674
Skin (g)	2092.2	2459.9	2328.3	2399.1	2486.3	210.8	0.695
Feet (g)	635.1	640.7	636.9	636.2	667.2	34.1	0.341
Kidney (g)	71.9	76.4	60.9	65.8	66.6	5.36	0.350
Liver (g)	310.0	334.8	275.8	286.8	284.8	24.87	0.487
Lung (g)	177.5	226.9	230.3	227.7	219.9	17.78	0.261
Heart (g)	106.6	96.8	96.0	96.4	119.3	8.01	0.218
Genital scrotum (g)	177.8	215.2	165.1	179.6	143.9	27.2	0.493
Empty alimentary canal (g)	1722.8	1449.7	1432.5	1792.7	1403.3	139.7	0.223
Empty reticulo-rumen (g)	585.0	543.8	458.8	555.8	446.6	52.6	0.310
Empty intestine (g)	790.8	561.2	636.6	862.9	544.0	92.5	0.125

SEM: Standard error of the means

Meat quality and consumer acceptability

As shown in *Table 7*, there was no observed effect of dietary *V. karroo* leaf meal inclusion on the $pH_{1\ h}$ and $pH_{24\ h}$. Dietary *V. karroo* did not affect ($P > 0.05$) the meat color 1 h post-mortem, water holding capacity, shear force, cooking loss and dressing percentage. However, there was treatment effect on meat color at 24 h post-mortem. Goats fed 25% *V. karroo* leaf meal had higher ($P < 0.05$) L* intensity than those on diets 30 or 40% inclusion levels. On average, no differences ($P > 0.05$) existed among treatments with respect to tenderness, juiciness, flavor, taste, aroma and overall acceptability (*Table 8*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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Table 7. *Effect of Vachellia karroo leaf meal inclusion level on meat quality of bucks fed a Setaria verticillata grass hay-based diet*

Variable	Treatment					SEM	*P* value
	$V_{20}S_{80}$	$V_{25}S_{75}$	$V_{30}S_{70}$	$V_{40}S_{60}$	$V_{50}V_{50}$		
Muscle pH							
pH_1	6.9	6.9	6.9	6.7	6.6	0.202	0.673
pH_{24}	5.9	5.9	5.7	5.8	5.9	0.156	0.744
Meat color 1 h post-mortem							
L*[1]	34.4	27.6	29.7	28.0	25.0	2.244	0.120
a*[2]	14.8	17.4	15.3	15.9	18.1	1.555	0.547
b*[3]	6.9	6.9	6.5	5.7	5.7	0.613	0.503
Meat color 24 h post-mortem							
L*[1]	34.2^{ab}	37.3^{a}	27.2^{b}	29.2^{b}	33.6^{ab}	2.295	0.041
a*[2]	16.4	15.6	20.1	17.6	15.1	2.071	0.493
b*[3]	8.3	6.7	10.9	6.5	7.9	1.730	0.421
Water-holding capacity (g)							
Initial	13.6	13.2	12.9	12.1	12.1	1.993	0.294
Final	13.1	12.8	12.3	11.7	11.5	1.963	0.308
Shear force (N)	36.6	35.1	31.4	31.8	33.3	4.729	0.920
Cooking loss (%)	38.2	38.0	35.7	37.7	40.3	1.799	0.449
Dressing percentage	35.5	36.8	35.9	34.6	39.7	1.675	0.318

[a,b]Means with different superscripts in the same row are significantly different ($P < 0.05$)
SEM: Standard error of the means
[1]Lightness
[2]Red intensity
[3]Yellow intensity

Table 8. *Consumer acceptability of meat from bucks fed dietary mixture of Vachellia karroo and Setaria verticillata grass hay*

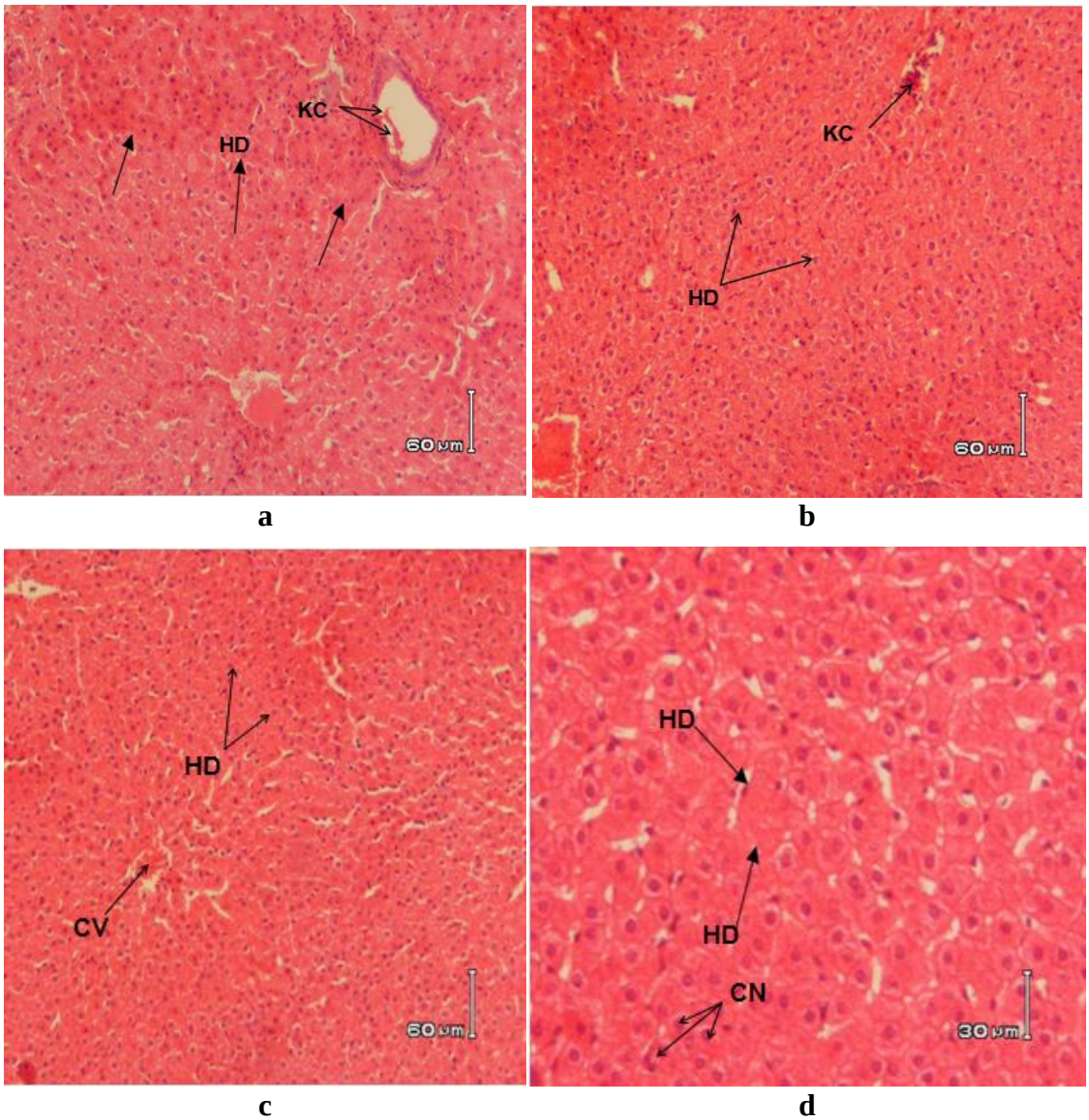
Sensory characteristic	Treatment					SEM	*P* value
	$V_{20}S_{80}$	$V_{25}S_{75}$	$V_{30}S_{30}$	$V_{40}S_{60}$	$V_{50}S_{50}$		
Tenderness	3.18	3.22	3.83	3.09	3.41	0.345	0.553
Juiciness	3.01	3.25	3.46	2.77	3.07	0.358	0.662
Flavor	3.15	3.29	3.59	3.46	3.51	0.305	0.802
Taste	3.21	3.34	3.55	3.64	3.51	0.305	0.852
Aroma	3.16	3.20	3.55	3.49	3.35	0.286	0.792
Overall acceptability	3.26	3.49	3.84	3.63	3.40	0.322	0.676

SEM: Standard error of the means

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1702_28932909

Effect of dietary Vachellia karroo on histological changes in the liver and kidney tissues of bucks

Histological analysis of the liver tissues of bucks fed 20, 25 or 30% *Vachellia karroo* leaf meal showed moderate hepatocellular hydropic degeneration, dilation of central veins and proliferation of sinusoidal kupfer cells (*Fig. 1a, b* and *c*, respectively). The hepatocytes of bucks fed diets containing 40 or 50% *V. karroo* leaf meal had severe hepatocellular hydropic degeneration with multifocal single cell and clustered cell necrosis (*Fig. 1d* and *e*, respectively). The kidney tissues of bucks fed 20, 25 or 30% *V. karroo* leaf meal had early dilatation of glomerular uriniferous spaces and mild renal tubular nephrosis (*Fig. 2a, b* and *c*, respectively), while those fed 40 or 50% *V. karroo* leaf meal had dilatation of uriniferous spaces and ectasia of some proximal convoluted tubules (*Fig. 2d* and *e*, respectively). Intra-tubular proteinaceous fluids with protein cast formation were also noticed in the kidney of bucks on diets 40 or 50% *V. karroo* leaf meal.



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DOI: http://dx.doi.org/10.15666/aeer/1702_28932909

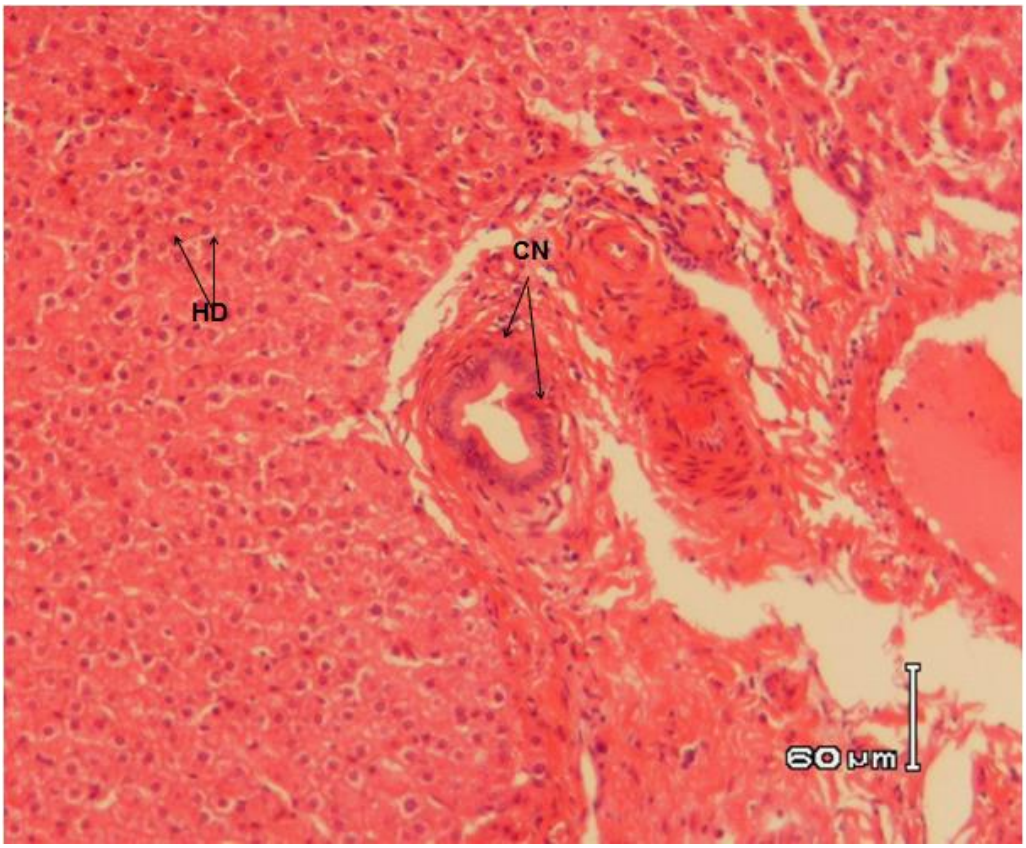

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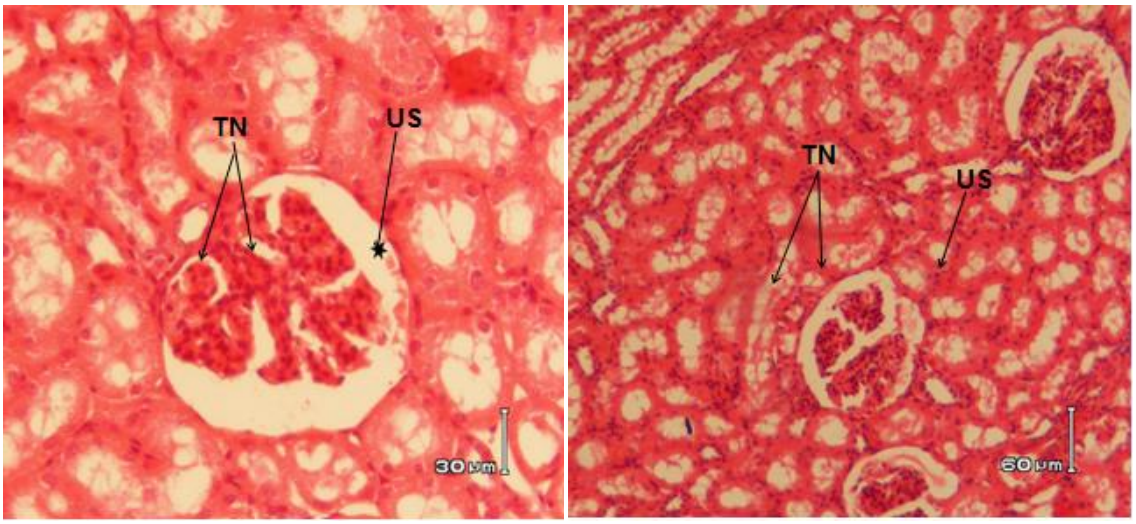
Figure 1. *Effect of V. karroo leaf meal inclusion on liver histology of bucks.* ***a*** *Moderate hepatocellular hydropic degeneration and proliferation of sinusoidal kupfer cells (20% V. karroo).* ***b*** *Moderate hepatocellular hydropic degeneration and proliferation of sinusoidal kupfer cells (25% V. karroo).* ***c*** *Moderate hepatocellular hydropic dilatation of central veins (30% V. karroo).* ***d*** *Severe hepatocyte degeneration and multifocal single cells (40% V. karroo).* ***e*** *Severe hepatocyte degeneration, multifocal single cell and clustered cell necrosis (50% V. karroo). Arrows point to hepatocellular hydropic degeneration (HD), kupfer cells (KC), central veins (CV) and cell necrosis (CN)*



a **b**

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DOI: http://dx.doi.org/10.15666/aeer/1702_28932909

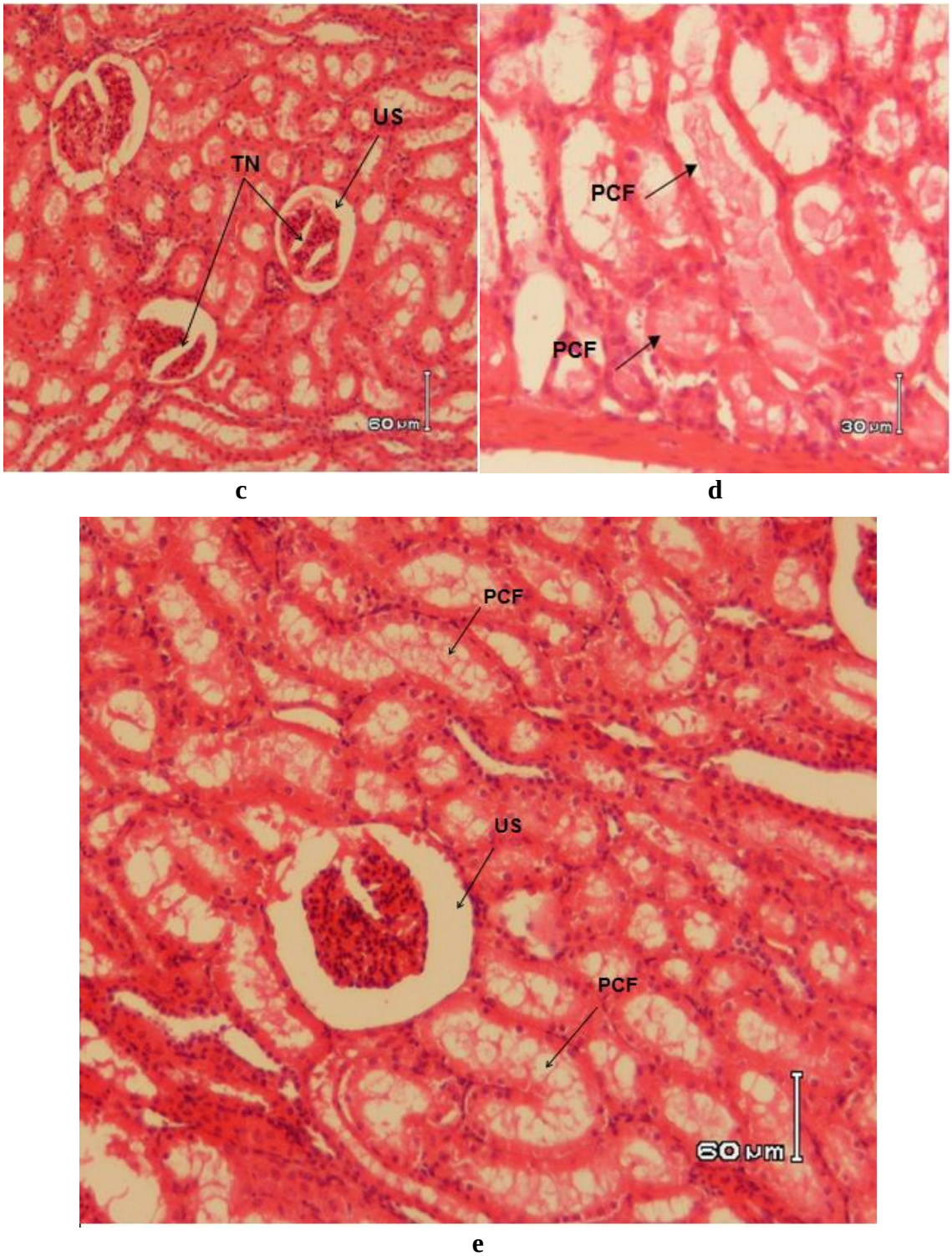

Figure 2. *Effect of V. karroo leaf meal inclusion on kidney histology of Pedi bucks.* ***a*** *Early dilatation of glomerular uriniferous space and mild renal tubular nephrosis (20% V. karroo).* ***b*** *Dilatation of glomerular uriniferious spaces and mild to moderate renal tubular nephrosis (25% V. karroo).* ***c*** *Dilatation of uriniferous spaces, moderate renal tubular nephrosis (30% V. karroo).* ***d*** *Dilatation of uriniferous spaces, intra-tubular proteinaceous fluid with protein cast formation (40% V. karroo).* ***e*** *Dilatation of uriniferous space, intra-tubular proteinaceous fluid with protein cast formation. Arrows points to tubular nephrosis (TN), uriniferous space (US) and protein cast formation (PCF)*

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Discussion

In the present study, *V. karroo* inclusion had no effect on diet intake of bucks. Similar results were reported for kids fed tanninferous *Ageritum conyzoides*, *Eupotarium odoratum* and *Crystellina* parasitica (Das et al., 2011). It has also been reported elsewhere that diets high in CT reduce intake of goats (Holechek et al., 1990). On the contrary, Solaiman et al. (2010) reported increased feed intake in Kiko crossbred male kids fed CT forage (*Sericea lespedeza*). Condensed tannins in forage legumes adversely affect feed intake through astringency in the oral cavity (Lamy et al., 2011). However, in the present study, diets with higher levels of CT were well-tolerated by goats. This may be due to the fact that the goats developed mitigatory systems against tannin toxicity such as secretion of proline-rich proteins in their saliva or proliferation of microorganisms resistant to condensed tannins in their digestive tracts (Lamy et al., 2011; Muir, 2011).

Dietary treatment did not improve growth performance of Pedi bucks. This is similar to the findings of Dludla (2010) who reported no differences in body weight gain of goats fed forages with different tannin concentrations. Wright (2015) observed similar results in Kiko-cross goats fed tanninferous *Sericea lespedeza*, pine bark powder and combination of *Sericea lespedeza* and pine bark powder. However, Ngambu et al. (2013) reported improved growth performance when Xhosa lop-eared goats were supplemented with 200 g of fresh *V. karroo* leaves. The lack of significant differences in body weight gain in the present study could be due to the fact that the dietary treatments met the nutrient requirements for a growing goat and hence nutrient supply was adequate for growth (McDonald et al., 2011).

Vachelia karroo leaf meal inclusion had no effect on the carcass weight and yields of Pedi bucks. Wright (2015) reported similar finding in Kiko-cross goats fed *Sericea lespedeza*, pine bark powder and combination of *Sericea lespedeza* and pine bark powder. The result obtained in the present study was expected since the dietary treatments did not influence average daily weight gains of goats.

According to Priolo et al. (2001), meat pH values can be influenced by dietary treatments. In the present study, *V. karroo* leaf meal inclusion had no effect on meat pH values. Previous studies demonstrated that the consumption of tanninferous feeds had no effect on chevon pH (Mapiye et al., 2010). However, Ngambu et al. (2013) observed significant differences in meat pH when goats were supplemented with *V. karroo* leaf meal. The discrepancies in the results could be due to the amount of dietary tannins ingested by the animals in each study. The ultimate pH (pH_u) of a carcass usually varies from 5.3 to 6.8 (Mostert, 2007). Under-nutrition is a primary cause of high pH_u in meats since animals do not have the possibility to accumulate sufficient glycogen reserve in their muscles (Bray et al., 1989). However, the experimental diets in the present study met the nutrient requirements for a growing goat and hence differences in meat pH values were not expected. Additionally, animals stressed prior to death are more likely to have a high pH_u. This is due to depletion of muscle glycogen resulting in lower lactic acid production. The animals in this study were not stressed prior to slaughter.

The present study indicated that goats fed 25% *V. karroo* leaf meal produced meat which was lighter than those on diets 30 or 40% leaf meal. Normally, consumers prefer lighter meat than dark meat. Verna et al. (1989) found similar result when lambs were fed two sorghum varieties with different tannin contents. Effect of tanninferous feed on meat lightness have also been reported by other authors (Priolo et al., 2001). It has been hypothesized that tannins present in forages are responsible for the differences found in

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meat color (Priolo et al., 2005). The effect of tannins on meat color is attributed to the reduced microbial biosynthesis of vitamin B_{12} (Priolo and Vasta, 2007). An increase in intramuscular and marbling fat is another factor that contributes to meat lightness (Baublits et al., 2004). However, the mechanism of action of forage tannins on meat color is not clear and merits further studies.

Dietary treatments had no effect on water holding capacity, shear force, cooking loss and dressing percentage of buck meat. These findings are similar to the report of Mapiye et al. (2010) who reported that beef from steers supplemented with *V. karroo* leaves had no effect on shear force, WHC, and cooking loss. Further research is needed to deepen the knowledge in this area. Meat sensory attribute values were also similar across the dietary treatments. Ngambu et al. (2012) however reported significant differences in consumer sensory attributes of meat from indigenous Xhosa lop-eared goat breed supplemented with different amounts of *V. karroo* leaves. It is not clear how dietary tannins affect the sensory attributes of goat meat and this may require further studies.

The liver is a primary site of detoxification and is generally the major site of intensive metabolism, hence, it is prone to various disorders as a consequence of exposure to toxins (Ganong, 2005). In the present study, goats fed 20, 25 or 30% *V. karroo* leaf meal inclusion had moderate hepatocyte degeneration, dilation of central veins and proliferation of sinusoidal kupfer cells. This is similar to the findings of Karimi et al. (2014), who reported mild congestion in central veins and sinusoidal abnormality when Merino lambs were fed tanninferous sorghum-based diets. Hervas et al. (2003) reported moderate hydropic degeneration in the hepatocytes of sheep dosed intra-ruminally with 3.0 g quebracho tannin extracts. The results indicate that the livers of the goats fed *V. karroo* leaf meal up to 30% were not adversely affected. However, severe hepatocyte degeneration was noticed in the liver of goats fed diets with 40 or 50% *V. karroo* leaf meal. Lesions associated with natural oak toxicosis characterized by hepatic and renal damage have been reported in cattle (Spier et al., 1987). Histological changes such as shrinkage of hepatocyte, degeneration and necrosis of hepatocytes around the central veins and degeneration of some hepatic sinusoids have been reported in lambs fed high tanninferous sorghum grain diets (Karimi et al., 2014). The present results showed that high *V. karroo* leaf meal inclusion levels of 40 or 50% in the ration may cause damages to the liver of bucks and hence such inclusion levels are not recommended.

The kidney is also an important organ for elimination of waste or toxic materials in the body. Exposure of the kidney to toxins may cause serious damages to this organ (Junqueira and Carneiro, 2003). However, the present study showed that the experimental diets did not cause any serious damage to the kidneys of the goats. This agrees with the findings of Silanikove et al. (1996) who reported no damage to the kidneys of goats fed tannin-containing leaves. On the contrary, Karimi et al. (2014) observed that high levels of sorghum grains in the diets induced histological changes in the kidneys of sheep. Some ruminants on tanninferous forage tend to develop adapted rumen microorganisms that detoxify plant secondary metabolites (Alonso-Diaz et al., 2010). The detoxification process may, however, cause adverse effects in ruminants as a consequence of increased enzymatic demand in the liver, kidney, gut mucosa and other tissues (Van Soest, 1994).

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Conclusions

Dietary *V. karroo* leaf meal levels in the present study did not improve feed intake, growth performance, carcass weight and carcass components of bucks. This may be an indication that the diets supplied adequate nutrients for growth of the goats. *Vachelia karroo* leaf meal did not adversely affect meat tenderness, juiciness, flavor, taste, aroma and overall acceptability. This is good for goat meat consumers, and requires further studies to confirm the responses. Meat pH, color, water-holding capacity, shear force, cooking loss and dressing percentage were not influenced by high and low *V. karroo* leaf meal levels. This is an indication that the diets had no adverse effects on these parameters. However, the effect of *V. karroo* on meat lightness was variable, depending on the inclusion level but without any recognizable pattern.

Vachelia karroo leaf meal inclusion levels of 20, 25 or 30% did not have adverse effects on livers and kidneys of bucks. However, severe hepatocyte degeneration was noticed in the liver of bucks fed diets with *V. karroo* leaf meal inclusion levels of 40 or 50%. Thus, *V. karroo* leaf meal inclusion levels of 20 to 30% are suggested. However, more detailed studies are recommended to confirm these results.

Acknowledgements. The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at are those of the authors and are not necessarily to be attributed to the NRF.

Conflict of interests. The authors declare no conflict of interests.

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