# International Journal of Veterinary Sciences and Animal Husbandry 

ISSN: 2456-2912
VET 2021; 6(5): 43-47
© 2021 VET
www.veterinarypaper.com
Received: 22-07-2021
Accepted: 24-08-2021

## F Kemboi

Department of Animal Science, Egerton University, Egerton, Kenya

JO Ondiek
Department of Animal Science, Egerton University, Egerton, Kenya

## AM King'ori

Department of Animal Science, Egerton University, Egerton, Kenya

## PA Onjoro

Department of Animal Science, Egerton University, Egerton, Kenya

JL Museti
Department of Animal Science, Egerton University, Egerton, Kenya

Corresponding Author:
F Kemboi
Department of Animal Science, Egerton University, Egerton, Kenya

# Economic benefit of inclusion of indigenous browses and tannin binders in growing Small East African goats' diets 

F Kemboi, JO Ondiek, AM King'ori, PA Onjoro and JL Museti

DOI: https://doi.org/10.22271/veterinary.2021.v6.i5a. 381


#### Abstract

A seventy (70) day feeding trial was conducted to determine the economic benefit of including indigenous browses and tannin binders in growing small east African (SEA) goat diets. To test the economic benefit of inclusion of indigenous browses, thirty (30) growing goats weighing $10.5 \mathrm{~kg} \pm 1.3$ (mean $\pm \mathrm{SD}$ ) were randomly assigned to the ten (10) experimental diets in a completely randomized design in a factorial arrangement with three replications. The browse leaves were supplemented at 0,15 , 30 , and $45 \%$ of the Acacia brevispica, Balanites aegyptiaca, and Berchemia discolor, respectively. For economic benefit determination of inclusion of tannin binders in indigenous browses, twenty-four (24) growing goats with bodyweight $10.5 \mathrm{~kg} \pm 1.3$ (mean $\pm \mathrm{SD}$ ) were randomly assigned to the Acacia brevispica, and Berchemia discolor diets with various levels of polyethylene glycol (PEG) and bentonite clay in a completely randomized design in a factorial arrangement. Feed cost per kilogram of gain (192.2 KES $/ \mathrm{kg}$ ) was significantly $(P<0.05)$ lower in the inclusion level of $45 \%$ A. brevispica (T4) leaf meal in comparison to the other inclusion levels. An increase in supplementation led to a lower feed cost per kilogram of gain (KES/kg). The feed cost per kg weight gain revealed that the addition of $45 \% \mathrm{~A}$. brevispica leaf meal as a supplement was the most cost-effective than other inclusion levels. Feed cost per kilogram of gain (KES/kg) was significantly $(P<0.05)$ lower and better in D3 (406.2) and D6 (392.3) compared to other dietary treatments where tannin binders were incorporated. Incorporating the bentonite clay as a tannin binder was better than PEG in terms of the cost of feed per kg gain. It was concluded that increasing levels of tree browse and use of bentonite was not only cheaper but also resulted in a higher weight gain.


Keywords: bentonite clay, feed cost, PEG 6000, weight gain

## Introduction

The rearing of livestock, especially goats in the pastoral areas, contributes to smallholder farmers' resilience and reduction of poverty and food insecurity ${ }^{[5]}$. Local browse species can form alternative feed resources to uphold good performance in goats without expensive concentrate diets ${ }^{[15]}$. Utilization of multipurpose trees and shrubs browse in the diet of ruminant animals will reduce the cost of production with an increase in weight gain of the animals ${ }^{[18]}$. Natural pastures and crop residues are low in crude protein (CP) content $(<8 \%)$, metabolizable energy (ME) ( $<8 \mathrm{MJ} / \mathrm{kg} \mathrm{DM}$ ), in-vitro dry matter digestibility ( $<50 \%$ ), vitamin and mineral contents, lower than the requirement for microbial function in the rumen ${ }^{[19]}$ in ruminant livestock. Native browses are rich in crude protein content, organic matter, and minerals that can be used as supplements to relieve the effects of low-quality feeds ${ }^{[14]}$ Despite the high nutritional content of native browses, their use in livestock feeding is hindered by a high content of polyphenolics, such as tannins ${ }^{[8]}$. Condensed tannins (CTs) lead to poor acceptability of forage, hence decreased feed intake of the browse forage ${ }^{[7]}$ Condensed tannins in the feed are known to affect the digestibility and availability of nutrients ${ }^{[19]}$. The quantity of tannins in native browses varies widely, and their effects on animals can be beneficial or toxic ${ }^{[10]}$. Inactivation of tannins by polyethylene glycol (PEG) may enhance the accessibility of nutrients by the animal and decrease microbial suppression leading to better animal performance ${ }^{[11]}$. Bentonite clay in animal nutrition is mainly used as a feed pelleting agent, adsorbing agents to mycotoxins, pesticides, heavy metals, phenols, and tannins ${ }^{[1,9]}$.

Mixing indigenous browses with grass hay-based diets can be an effective method of reducing the adverse effects of antinutritive factors such as tannins ${ }^{[2]}$.
Growing SEA goats were offered a basal diet of Rhodes grass hay, maize germ, tannin binders (PEG and bentonite), and varying levels of indigenous browses (Acacia brevispica, Balanites aegyptiaca, and Berchemia discolor). The nutritive value, feed intake, weight gain, feed conversion ratio (FCR), and apparent digestibility coefficients of the diets were used to determine the economic benefit of including the indigenous browses and tannin binders in the diets.

## Materials and Methods <br> Experimental and Forage Collection Site

The experiment was conducted in Marigat Sub-County, Baringo County, Kenya, which is 1080 m above sea level. It receives $700-950 \mathrm{~mm}$ rainfall per year with peaks in April/May and July/August, but it is generally very erratic. The annual mean temperature is $23{ }^{\circ} \mathrm{C}{ }^{[20]}$. The forage was collected from indigenous browse trees and shrubs in Marigat

## Preparation of experimental diets

Leaf samples of the Acacia brevispica, Balanites aegyptiaca, and Berchemia discolor were harvested by hand stripping from the trees on communal grazing ranges in Marigat SubCounty during the dry season (Dec. to Jan). After harvesting, the forage was spread on a sheet and air-dried under shade for seven days. The dried forages were put in sacks and stored in a well-ventilated room. The basal diet (control) was Rhodes grass (Chloris gayana) hay, and maize germ was formulated according to the animal requirements ${ }^{[13]}$. Rhodes grass was purchased and chopped through a 4 mm screen hammer mill. Forages for the experimental diets were ground to pass through a 4 mm sieve hammer mill.

Experimental Animals, Design, Feeding, and Management To test the economic benefit of inclusion of indigenous browses, thirty (30) growing goats weighing $10.5 \mathrm{Kg} \pm 1.3$ (mean $\pm$ SD) were randomly assigned to the experimental diets at different inclusion levels in a completely randomized design in a factorial arrangement with three replications. The browse leaves were supplemented at $0,15,30$, and $45 \%$ of Acacia brevispica, Balanites aegyptiaca, and Berchemia discolor, respectively. The goats were allocated to individual pens ( $1.5 \times 2.5 \mathrm{~m}$ ). Feed, water, and mineral salt were offered ad-libitum. All the animals were in good health from the beginning up to the end of the feeding trial.
The basal diet and supplements were offered individually in a separate feeding trough. The supplements were offered daily at different levels per head on DM basis at 08:00 hr to let the goats eat the supplements before offering the basal diet. The refusals from supplements were collected before offering the basal diet, weighed, and recorded. The mixture of Rhode grass hay and maize (Zea mays) germ was introduced at 09:00 hr after goats had consumed the supplement. The mixture of hay and maize germ were offered at $450 \mathrm{~g} / \mathrm{head}$ on a DM basis to ensure it is ad-libitum. Feed refusals were collected, weighed, and recorded every day in the morning before offering fresh hay. The data were collected for eight weeks.

## The experimental treatment diets were

T1. Rhodes grass hay ad libitum plus 100 g maize germ (control).
T2. Control plus $15 \%$ A. brevispica.
T3. Control plus 30\% A.brevispica

T4. Control plus 45\% A. brevispica.
T5. Control plus $15 \%$ B. aegyptiaca.
T6. Control plus $30 \%$ B. aegyptiaca
T7. Control plus 45\% B. aegyptiaca.
T8. Control plus 15\% B. discolor.
T9. Control plus $30 \%$ B. discolor
T10. Control plus 45\% B. discolor
For determination of economic benefit of inclusion of tannin binders in indigenous browses- based diets, twenty-four (24) growing goats weighing $10.5 \mathrm{Kg} \pm 1.3$ (mean $\pm$ SD) were randomly assigned to the Acacia brevispica and Berchemia discolor based diets with various levels of PEG and bentonite in a factorial completely randomized design. The goats were allocated to individual pens, with each treatment having three replicates. The experiment lasted 70 days, consisting of a $14-$ day adaptation period. The selected local browses leaf meal was treated with PEG at $25 \mathrm{~g} / \mathrm{Kg}$ and bentonite clay at 20 $\mathrm{g} / \mathrm{Kg}$. Tannin binding agent, PEG 6000 molecular weight (MW), was purchased from Kobian (Kenya) Ltd. The local test browse was offered in a separate trough at 200 g DM at 07:30hr before the provision of basal diet up to 09:00 hr. The PEG was administered to animals by spraying it on the leaves of indigenous browses ${ }^{[21]}$. The goats were given free access to clean drinking water and salt licks. The weighing was done every week from 0700 hr to 0830 hr throughout the trial period. The treatments diets were:
D1. Hay plus 100 g maize + A. brevispica + PEG
D2. Hay plus 100 g maize + A. brevispica + Bentonite
D3. Hay plus 100 g maize + A. brevispica - Tannin binders
D4. Hay plus 100 g maize + B. discor +PEG
D5. Hay plus 100 g maize $+B$. discor + Bentonite
D6. Hay plus 100 g maize + B. discor - Tannin binders

## Data Collection

Performance was measured as weight gain, and feed intake was recorded every week. Goats were weighed every week. Average daily gain (ADG), which is the rate of weight gain per day over a specified period, was determined. Feed conversion ratio (FCR) was calculated as feed intake divided by the live weight gain over a given period. Feed offered and refusals were recorded every day, and feed intake was calculated by the difference between feed offered and feed refusal.

## Economic analysis

Product of total feed eaten and feed cost per kg was used to calculate the feed cost to ADG ratio (FC: ADG) according to the methodology described by ${ }^{[4]}$, which compares the feed cost for 1 kg weight gain by the animal. Total feed cost was then computed as the product of total feed intake during the experimental period and the price per kg of each diet. Therefore, the total feed cost per kilogram of gain (KES/Kg) equals total feed cost divided by total body weight gain. The current price per kg of Acacia brevispica, Balanites aegyptiaca and Berchemia discolor, and Rhodes grass hay was computed based on the collection fee paid, transportation cost, and the cost for milling and chopping. The cost of inclusion of PEG (6000) and bentonite clay was calculated based on their current market price.

Feed cost per weight gain $=\frac{\text { Feed cost }(\mathrm{Ksh} / \mathrm{kg}) \times \text { Feed intake per head } / \mathrm{kg}}{\text { Weight gain per head } / \mathrm{kg}}$

## Statistical Analysis

Data collected on feed intake, digestibility, FCR, average daily gain(ADG), and FC : ADG (KES/kg were subjected to the analysis of variance using the General linear model procedure of statistical analysis system ${ }^{[22]}$ version 9.0, where initial live weight was fitted as a covariate in the analysis of feed intake and live weight changes. Significant means were separated using Tukey's HSD (Tukey's Honestly Significant Difference Test) at 5\% significance. The model for a factorial used for statistical analysis was:

$$
Y_{i j k}=\mu+A_{i}+B_{j}+(A B)_{i j}+\varepsilon_{i j k}
$$

where
$\boldsymbol{Y}_{i / k}=$ is the response variable
$\boldsymbol{\mu}=$ the overall mean
$\boldsymbol{A}_{i}=$ is the effect of browse inclusion level
$\boldsymbol{B}_{j}=$ is the effect of treatment diet during feeding (T1, ...T3)
$(A B)_{i f}=$ the effect of the interaction between the inclusion level and treatment diet
$\varepsilon_{i j k}=$ random error term

## Results and Discussion

The Dry matter intake, average daily gains, feed cost to ADG ratio (FC: ADG), and apparent nutrient digestibility of Small East African goats fed on 3 selected browses and Rhodes grass as control is presented in Table 1.

Table 1: Dry matter feed intake, average daily gains, FC: ADG (KES/kg) and apparent nutrient digestibility of Small East African goats fed on 3 selected browses and Rhodes grass as control

| Dietary treatments |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Parameters | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | SEM | $\mathbf{P}$ |
| DM Intake (g/day) | $213.3{ }^{\text {d }}$ | $316.9^{\text {b }}$ | $354.49^{\text {a }}$ | $335.42^{\text {ab }}$ | $246.04{ }^{\text {d }}$ | $269.08^{\text {d }}$ | $304.73{ }^{\text {c }}$ | $289.02^{\text {cd }}$ | $264.35^{\text {d }}$ | $308.42^{\text {b }}$ | 6.446 | <. 0005 |
| Total DMI \% | $43.61{ }^{\text {d }}$ | 64.79 ${ }^{\text {b }}$ | $72.48^{\text {a }}$ | $68.57^{\text {a }}$ | $49.76^{\text {c }}$ | $54.41^{\text {c }}$ | $61.62^{\text {b }}$ | $59.09^{\text {b }}$ | $54.04^{\text {c }}$ | $62.82^{\text {b }}$ | 1.312 | <. 0005 |
| ADG ( $\mathrm{gd}^{-1}$ ) | $9.97^{\text {c }}$ | $24.98^{\text {a }}$ | $29.95{ }^{\text {a }}$ | $28.97^{\text {a }}$ | $14.97^{\text {c }}$ | $18.08^{\text {b }}$ | $20.03^{\text {ab }}$ | $18.98^{\text {b }}$ | $18.09^{\text {ab }}$ | $21.99^{\text {ab }}$ | 7.31 | 0.0005 |
| Initial weight(kg) | $12.0{ }^{\text {a }}$ | $11.83{ }^{\text {a }}$ | $12.27^{\text {a }}$ | $12.13^{\text {a }}$ | $12.0^{\text {a }}$ | $10.43^{\text {a }}$ | $11.03^{\text {a }}$ | $11.87^{\text {a }}$ | $10.30^{\text {a }}$ | $11.63^{\text {a }}$ | 0.481 | <. 0001 |
| Final weight(kg) | $12.56^{\text {ab }}$ | $13.23^{\text {ab }}$ | $13.95{ }^{\text {a }}$ | $13.76^{\text {a }}$ | $12.84{ }^{\text {a }}$ | $11.44^{\text {b }}$ | $12.15^{\text {ab }}$ | $12.93{ }^{\text {ab }}$ | $11.31^{\text {b }}$ | $12.87^{\text {ab }}$ | 0.481 | <. 0001 |
| FCR | $21.4{ }^{\text {a }}$ | $12.69^{\text {e }}$ | $11.83{ }^{\text {ef }}$ | $11.58^{\text {f }}$ | $16.44{ }^{\text {b }}$ | $14.88^{\text {c }}$ | $15.21^{\text {c }}$ | $15.23^{\text {c }}$ | $14.61{ }^{\text {cd }}$ | $14.03{ }^{\text {d }}$ | 0.382 | <. 0001 |
| FC:ADG (KES/kg) | $420.4^{\text {a }}$ | $233.4^{\text {ed }}$ | $203.6^{\text {f }}$ | $192.2^{\text {f }}$ | $297.5^{\text {b }}$ | $247.4^{\text {d }}$ | $238.9^{\text {ed }}$ | $277.2^{\text {c }}$ | $247.4^{\text {d }}$ | $226.6^{\text {e }}$ | 6.818 | <. 0001 |
| Cost/kg feed (KES) | 19.6 | 18.4 | 17.2 | 16.6 | 18.1 | 16.6 | 15.7 | 18.3 | 16.9 | 16.2 |  |  |

FC=feed cost, ADG=average daily gain, SEM = Standard Error of Means.
$\mathrm{a}, \mathrm{b}, \mathrm{c}, \mathrm{d}$ Means in the same row with different superscripts are significantly different $(P<0.05)$.

Effects of incorporation of selected browse species on performance of growing goats
All animals were in good condition until the completion of the experiment. All the experimental diets resulted in a positive weight gain; however, the highest average gain was observed in T2, T3, T4, and lowest in T1 (basal). The results on the goat's performance indicated significant ( $P<0.05$ ) dietary treatments' effects on growth performance among the growing goats. There was no significant difference between T2, T3, and T4 in terms of daily weight gain. Dry matter intake was highest in T3 and T4 and lowest in T1. Total dry matter intake increased with supplementation with indigenous browse diets, which agrees with the previous studies involving similar forages ${ }^{[5,12]}$. Feed conversion ratio (FCR) was highest in T1 compared to the other dietary treatments. The goats in the study readily ate all supplements. High intake of T3 and T4 could be due to low levels of anti-nutritive factors, especially tannins ${ }^{[17]}$. Findings reported on feed supplementation trials with indigenous browse species revealed higher live weight gain compared to the basal or control diet ${ }^{[18,14,12]}$.
Economic benefit of inclusion of indigenous browses as feed to growing goats
On the economic assessment, cost per kg of feed varied across all inclusion levels, with T1 recording the highest value while T7 was the lowest (Table 1 and fig.2). The reduction in the cost of feed per Kg may be due to an increase in the level of supplementation and lower collection fee paid on $B$. aegyptiaca compared to other indigenous browse species. Substitution of conventional feed ingredients with unconventional feed ingredients reduced the cost of feed ${ }^{[23]}$. Feed cost per kilogram of gain (KES/Kg) was significantly ( $P<0.05$ ) lower in T3 and T4 as compared to other inclusion levels. The feed cost per kg gain in the study revealed that
adding 30 and $45 \%$ A. brevispica (T3 and T4) leaf meal as a supplement was more cost-effective than other inclusion levels. For each browse, an increase in supplementation led to a decrease in feed cost per kilogram of gain (KES/Kg). This was similar to the results reported by ${ }^{[18]}$ on cost-benefit analysis of inclusion levels and feeding frequency of Ficus sycomorus supplement in yankasa rams fed Digitaria. smutsii basal diet.
On the other hand, the cost of feed per kg gain, feed intake, and cost $/ \mathrm{kg}$ feed were similar ( $P>0.05$ ) in T6 and T9 (Table 1). The high feed cost per kg weight gain (KES/Kg) observed in T1 ( $0 \%$ inclusion level of indigenous browse species) may result from a high quantity of maize germ in the formulated ration, which is more expensive than locally available indigenous browse species. This study shows that the addition of indigenous browse species in the diet of growing goats resulted in decreased cost of feed per kg gain and increased live weight gain.


Fig 1: Comparison of mean FC : ADG ratio between research diets

The growth performance of the Small East African goats is shown in Table 2.
Table 2: Dry matter feed intake, average daily gain, FC: ADG (KES/kg) and apparent nutrient digestibility of Small East African goats fed on two selected browses treated with tannin binders

| Parameters | D1 | D2 | D3 | D4 | D5 | D6 | SEM | P |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| DM Intake (g/day) | $431.8^{\text {a }}$ | $431.8^{\text {a }}$ | $435.6^{\text {a }}$ | $386.2^{\text {c }}$ | $423.7{ }^{\text {a }}$ | $408.1{ }^{\text {b }}$ | 3.461 | <. 00001 |
| Total DMI \% | $88.26^{\text {a }}$ | $88.28^{\text {a }}$ | $89.05^{\text {a }}$ | $78.96{ }^{\text {d }}$ | $86.62^{\text {b }}$ | $83.43^{\text {c }}$ | 0.708 | <. 0005 |
| ADG ( $\mathrm{gd}^{-1}$ ) | $28.2^{\text {a }}$ | $31.1^{\text {a }}$ | $17.80^{\text {c }}$ | $25.39^{\text {b }}$ | $25.3{ }^{\text {b }}$ | $16.8^{\text {c }}$ | 7.31 | 0.0006 |
| Initial weight(kg) | $11.37^{\text {a }}$ | $11.83{ }^{\text {a }}$ | $11.07{ }^{\text {a }}$ | $8.83{ }^{\text {a }}$ | $10.43{ }^{\text {a }}$ | $10.23{ }^{\text {a }}$ | 1.043 | <. 0001 |
| Final weight(kg) | $12.94{ }^{\text {a }}$ | $13.57^{\text {a }}$ | $12.06^{\text {a }}$ | $10.26^{\text {a }}$ | $11.85{ }^{\text {a }}$ | $11.17^{\text {a }}$ | 1.042 | <. 0001 |
| FCR | $15.4{ }^{\text {c }}$ | $13.9{ }^{\text {d }}$ | $24.5{ }^{\text {a }}$ | $15.2^{\text {c }}$ | $16.7{ }^{\text {b }}$ | $24.3{ }^{\text {a }}$ | 0.155 | <. 0001 |
| FC:ADG (KES/kg) | $7060.6^{\text {a }}$ | 1110.4c | $406.2^{\text {d }}$ | $6957.4^{\text {a }}$ | 1327.9b | $392.3{ }^{\text {d }}$ | 40.76 | <. 0001 |
| Cost/kg feed (KES) | 457.8 | 79.72 | 16.6 | 457.4 | 79.3 | 16.2 |  |  |

$\mathrm{FC}=$ feed cost, $\mathrm{ADG}=$ average daily gain, $\mathrm{SEM}=$ Standard Error of Means.
$\mathrm{a}, \mathrm{b}, \mathrm{c}, \mathrm{d}$ Means with different superscripts in the same row are significantly different ( $P<0.05$ ).

Effects of Tannin binders' inclusion on growth performance of growing goats fed on selected browse species
All goats were in good condition until the completion of the experiment. Diets treated with binders had higher DM Intake, daily weight gains, and total dry matter intake. Polyethylene glycol 6000 and bentonite addition did not affect $(P>0.05)$ the digestibility coefficients. This was similar to the results reported by ${ }^{[3]}$ on the effect of PEG 4000 supplementation on the performance of yearling male Pedi goats fed a dietary mixture of Acacia karroo leaf meal and Setaria verticillata grass hay.
All animals had a positive performance, especially weight gains. Acacia brevispica treated with binders resulted in better performance than treated Bechemia discor due to more tannin binding in A. brevispica leading to high dry matter intake.
This was similar to the results reported by ${ }^{[6]}$ on increased performance of sheep fed Acacia saligna treated using PEG or sodium bentonite. There was a significant difference ( $P<0.05$ ) in the average daily gain and feed conversion ratio and weight gain of the experimental goats. The diet with Acacia brevispica and Berchemia discolor can be suitable as protein sources since they are rich in protein, locally available, and affordable.

## Economic benefit of including PEG 6000 and bentonite clay on growth performance of growing goats fed on selected browse species

Feed cost per kilogram of gain (KES/kg) was lowest ( $P<0.05$ ) in D3 and D6 compared to other dietary treatments where tannin binders were incorporated. This is due to the high cost of PEG and bentonite clay. The PEG and bentonite clay were very effective in the reduction of tannins which led to an increase in daily body weight gains in growing goats compared to diets without binders (Table 2 and figure 2). Cost per kg of feed varied across all inclusion levels, with D1 recording the highest value while D6 was the lowest. The cost of feed per kg gain was similar $(P>0.05)$ in D3 and D6; D1 and D4.
The addition of tannin binders led to a higher feed cost per kilogram of gain (KES/kg). Incorporating the bentonite clay as a tannin binder was better than PEG in terms of cost of feed per kg gain (Table 2). This is because of the low price of bentonite clay compared to PEG. Polyethylene glycol is extensively used to reduce the undesirable effects of tannins in animal rations, but due to high cost, especially in developing countries, it is, therefore, economical to use
alternative binders such as bentonite that is cheap and available ${ }^{[6]}$.


Fig 2: Comparison of mean FC: ADG ratio between research diets treated with binders

## Conclusions

- An increase in supplementation led to a better feed cost per kilogram of gain (KES/kg). The addition of 30 and $45 \%$ A. brevispica leaf meal as a supplement was more cost-effective than other inclusion levels.
- The addition of indigenous browse species in the diet of growing goats led to decreased cost of feed per kg gain and increased live weight gain.
- Incorporating the bentonite clay as a tannin binder was better than PEG in terms of the cost of feed per kg gain.


## Acknowledgement

The authors are grateful to CESAAM program for funding the research, Egerton University Animal Sciences Department for laboratory analyses services, M Mutumba, K Mwavishi, N K Kibitok for technical assistance and to the Dryland Research Training and Ecotourism Centre Chemeron, Baringo County, Kenya for providing the goats and research facilities

## References

1. Ambula M K, Oduho, G W and Tuitoek, J K. Effects of high-tannin sorghum and bentonite on the performance of laying hens. Tropical animal health and production 2003;35(3):285-292.
2. Bhat T K, Kannan A, Singh, B and Sharma O. P. Value addition of feed and fodder by alleviating the antinutritional effects of tannins. Agricultural Research 2013;2(3):189-206.
3. Brown D, Ng'ambi JW. 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 and production 2017;49(5):10511057.
4. Choi HB, Jeong JH, Kim DH, Lee Y, Kwon H, Kim YY. Influence of rapeseed meal on growth performance, blood profiles, nutrient digestibility, and economic benefit of growing-finishing pigs. Asian-Australasian journal of animal sciences 2015;28(9):1345.
5. Deng MT, Ondiek JO, Onjoro PA. Chemical composition and in vitro gas production of lesser-known South Sudan browse species. Livestock Research for Rural Development 2017, 29. Article \#81. Retrieved June 27, 2021, from http://www.lrrd.org/lrrd29/4/mame29081.html.
6. Ghandour MMA, Fayed AM, Abdul-Aziz GM, Hanafy MA. Effect of using polyethylene glycol or sodium bentonite on the performance of sheep-fed Acacia saligna. World. Applied Science Journal 2014;32:23092316.
7. Hagerman AE. The Tannin Handbook 2011. http://chemistry.muohio.edu/hagerman/.
8. Hlatini VA, Ncobela CN, Zindove TJ, Chimonyo M. Use of polyethylene glycol to improve the utilization of leguminous leaf meals in pigs: A review. South African Journal of Animal Science 2018;48(4):609-620.
9. Huwig A, Freimund S, Käppeli O, Dutler H. Mycotoxin detoxication of animal feed by different adsorbents. Toxicology Letters 2001;122(2):179-188.
10. Lamy E, Baptista ES, Coelho AV, Silva F. Morphological alterations in salivary glands of mice (Mus musculus) submitted to tannin enriched diets: comparison with sialotrophic effects of sympathetic agonists stimulation. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 2010;62(4):837-844.
11. Makkar HPS. Effects and fate of tannins in ruminant animals, adaptation to tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. Small Ruminant Research 2003;49:241-256.
12. Mangara JLI. Evaluation of the nutritive value of selected indigenous tree browses as feed for ruminant livestock in South Sudan (Doctoral dissertation, Egerton University) 2018.
13. National Research Council (NRC), Committee on the Nutrient Requirements of Small Ruminants, Board on Agriculture, Division on Earth, and Life Studies. Nutrient requirements of small ruminants: sheep, goats, cervids, and new world camelids 2007.
14. Ondiek JO, Ogore PB, Shakala EK, Kaburu GM. Feed intake, digestibility, and performance of Small East African goats offered maize (Zea mays) stover supplemented with Balanites aegyptiaca and Acacia tortilis leaf forages. Journal of Agricultural Science and Review 2013;2,21-26.
15. Okoruwa MI, Okoh PI, Akazue RC. Dietary Supplementation with Eclipta Alba and Polyalthia Longifolia Foliages on Digestibility, Feeding Behaviour, Blood Profile and Carcass Characteristics of Goats. European Journal of Agriculture and Food Sciences, 2020;2(4).
16. Osuga IM, Abdulrazak SA, Muleke CI, Fujihara T. Effect of supplementing Rhodes grass hay (Chloris gayana) with Berchemia discolor or Zizyphus mucronata on the
performance of growing goats in Kenya. Journal of Animal Physiology and Animal Nutrition 2012;96(4):634-639.
17. Osuga IM, Wambui CC, Abdulrazak SA, Ichinohe T, Fujihara T. Evaluation of nutritive value and palatability by goats and sheep of selected browse foliages from the semi-arid area of Kenya. Animal Science Journal 2008;79(5):582-589.
18. Yashim SM. Cost-benefit analysis of inclusion levels and feeding frequency of ficus sycomorus supplement in yankasa rams fed D. smutsii basal diet. Journal of Animal Production Research 2016;28(1):235-244.
19. Yisehak K, De Boever JL, Janssens GPJ. The effect of supplementing leaves of four tannin-rich plant species with polyethylene glycol on digestibility and zootechnical performance of zebu bulls (Bos indicus). Journal of Animal Physiology and Animal Nutrition 2014;98(3):417-423.
20. FAO (Food and Agriculture Organization) Fuelwood/ Afforestation and Extension in Baringo-Phase II, Kenya. Project findings and recommendations. FAO/Government cooperative program. FO: GCP/KEN/051/AUL 1992.
21. Salem HB, Nefzaoui A, Salem LB, Tisserand JL. Deactivation of condensed tannins in Acacia cyanophylla Lindl. foliage by polyethylene glycol in feed blocks: Effect on feed intake, diet digestibility, nitrogen balance, microbial synthesis and growth by sheep. Livestock Production Science 2000;64(1):51-60.
22. SAS. Statistical Analysis System Institute. SAS User's Guide. Statistics, Software Version 9.00, SAS Institute, Cary, North Carolina, USA 2002.
23. Adegbola TA, Okonkwo JC. Nutrient intake, digestibility and growth rate of rabbits fed varying levels of cassava leaf meal. Nigerian Journal of Animal Production 2002;29(1):21-26.
