**Short note [Nota corta]**

# EFFECTS OF FEEDING *Lantana camara* LEAF HAY ON ANIMAL PERFORMANCE AND HEALTH IN SMALL EAST AFRICA GOAT BREEDS †

# [EFECTOS DE LA ALIMENTACIÓN CON HENO HOJA DE *Lantana camara* SOBRE EL RENDIMIENTO Y SALUD ANIMAL EN CABRAS DE LA RAZA "SMALL EAST ÁFRICA"]

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## SUMMARY

**Background:** *Lantana camara* is listed as one of the worst invasive species worldwide and is considered poisonous to livestock. However, in invaded Zimbabwean rangelands, voluntary intake by domestic livestock especially goats of this shrub is common, yet, little is understood about the effect of this browse on animal performance. **Objectives:** To assess the effects of feeding graded levels of *L. camara* (LC) leafy hay on the performance, digestibility, nitrogen balance and microbial protein synthesis in Small East Africa Goat Breeds. **Methodology:** Eighteen, six to ten months old castrated goats with a mean± (SD) weight of 13.6±4.9 kg were randomly assigned to the six treatment diets in a completely randomised design. Each goat was housed separately in a metabolism cage for the entire experimental period of 21 days. *Lantana camara* leaf hay was incorporated in goat feed as a protein source at 5%, 10%, 15%, 20%, and 25% inclusion levels. Commercially bought, goat feed was used as the sixth and control treatment diet. Veld hay was used as a basal diet and water were offered *ad-libitum*. **Results**: The average daily dry matter intake was above the minimum recommended of 3% of the animal's metabolic body weight ($kg^{0.75}$). Goats fed on 10%LC consumed significantly lower quantities of hay than 5%LC but were not significantly different from goat feed (GF), 15%LC, 20%LC and 25%LC. Apparent digestibility coefficient values ranged from 62% to 71%. Higher nitrogen intakes was observed with diets that were highly palatable such as commercial goat feed and 5% *L. camara*. Higher microbial protein supply was observed in groups fed diets with high levels of *L. camara*. **Implications:** The use of invasive *L. camara* biomass as a source of goat feed at 5% inclusion is a promising method to control its spread in while addressing the nitrogen deficiencies experienced by livestock that subsist on poor quality feeds in invaded rangelands. **Conclusion:** Supplementing goats with *L. camara* leafy hay improves dry matter feed intake and degradability. Contrary to expectations, no negative effects were observed with *L. camara* leafy meal inclusion in goats diets at 5 to 25 percent inclusion level.
**Key words**: digestibility; *Lantana camara* leaf meal; protein supplement; purine derivatives.

## RESUMEN

**Antecedentes:** *Lantana cámara* está catalogada como una de las peores especies invasoras del mundo considerada venenosa para el ganado. Sin embargo, en los pastizales invadidos de Zimbabwe, la ingesta

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voluntaria de este arbusto por el ganado doméstico, especialmente las cabras, es común; sin embargo, se sabe poco sobre el efecto de este ramoneo en el rendimiento de los animales. **Objetivos:** Evaluar los efectos de la alimentación con niveles crecientes de heno de hoja de *L. camara* (LC) sobre el comportamiento, digestibilidad, balance de nitrógeno y la síntesis de proteínas microbianas en la raza pequeña de África Oriental. **Metodología:** 18 cabras castradas de seis a diez meses de edad con un peso medio ± (DE) de 13.6 ± 4.9 kg se asignaron aleatoriamente a las seis dietas de tratamiento en un diseño completamente aleatorizado. Cada cabra se alojó por separado en una jaula de metabolismo durante todo el período experimental de 21 días. El heno de hojas de LC se incorporó al alimento de las cabras como fuente de proteína a niveles de inclusión del 5%, 10%, 15%, 20% y 25%. El alimento para cabras, comprado comercialmente, se utilizó como dieta de tratamiento sexto y de control. El heno Veld se utilizó como dieta basal y se ofreció agua *ad libitum*. **Resultados:** La ingesta diaria promedio de materia seca estuvo por encima del mínimo recomendado del 3% del peso corporal metabólico del animal ($kg^{0.75}$). Las cabras alimentadas con 10% LC consumieron cantidades significativamente menores de heno que 5% LC pero no fueron significativamente diferentes del alimento para cabras (GF), 15% LC, 20% LC y 25% LC. Los valores del coeficiente de digestibilidad aparente oscilan entre el 62% y el 71%. Se observaron ingestas más altas de nitrógeno en las dietas mejor consumidas como el pienso comercial para cabras y un 5% LC. Se observó una mayor ingesta de nitrógeno con dietas que eran muy apetitosas, como el pienso comercial para cabras y el 5% de *L. camara*. Se observó un mayor suministro de proteína microbiana en grupos alimentados con dietas con altos niveles de *L. camara*. **Implicaciones:** El uso de biomasa invasora de *L. camara* como fuente de alimento para cabras con una inclusión del 5% es un método prometedor para controlar y monitorear su propagación mientras se abordan las deficiencias de nitrógeno que experimenta el ganado que subsiste con alimentos de mala calidad en los pastizales invadidos. **Conclusión:** La suplementación de las cabras con heno de hojas de *L. camara* mejora el consumo de materia seca y la degradabilidad. Contrariamente a las expectativas, no se observaron efectos negativos con la inclusión de harina de hojas de *L. camara* en las dietas de las cabras con un nivel de inclusión del 5 al 25 por ciento.

**Palabras clave:** digestibilidad; Harina de hojas de *Lantana camara*; suplemento proteico; derivados de purina.

## INTRODUCTION

Ruminants, mainly goats and cattle, have been observed consuming *Lantana camara, ad-libitum* in Zimbabwean rangelands (Gusha, *et al.*, 2016). Yet, this invasive shrub native to the Americas has been reported to be poisonous to livestock due to the secondary plant metabolites such as Lantadene A and B (Ghisalberti, 2000; Day *et al.*, 2003). For example, toxicity leading to death in Boar goat kid was reported in South Africa by Ide and Tutt (1998). *Lantana camara* is among the world's most invasive plant species (Sharma *et al.*, 2005; Day *et al.*, 2003), and is widespread and abundant in Zimbabwe (Chatanga, 2007, Gusha *et al.*, 2017, Masocha *et al*., 2017). While some studies reported that *L. camara* is toxic to livestock, others have reported that the species has high crude protein (>22% CP) and (>67%) digestibility (Osuga *et al.*, 2005). Therefore, exploring the potential uses of *L. camara*, as a protein supplement to ruminants grazed in invaded tropical and subtropical rangelands with poor quality native grass biomass is necessary.

Ruminants, especially goats are an ideal group for such a study because they have evolved to subsits on poor quality roughages provided the microbes in the rumen obtain adequate sources of nitrogen (N) and energy for microbial protein production. Several microbes such as *Ruminococcus flavefacians, Ruminococcus albus, Bacteriodes succinogenes,* and *Butyrivibrio fibrisolvens* are resident in the rumen (De Ondarza, 2008; De Ondarza and Engstrom, 2009). These microbes perform dual important roles in the degradation of fibrous feeds and provision of amino acids for the host animal. Previous work has estimated that 50% of amino acids absorbed from the small intestines are of rumen microbial protein origin (Dewhurst *et al.*, 2000). However, little is known about nutritive value, microbial protein production, and efficiency of utilisation of *L. camara* biomass nitrogen in ruminants that feed on this invasive shrub or given the biomass as a protein supplement.

It is estimated that 30% of Zimbabwean rangelands have been degraded through the increase of *L. camara* and other less palatable plant species (Gusha *et al.*, 2017). Communal cattle and goats have been observed consuming the shrub with no adverse effects (Osuga *et al.*, 2005, Gusha *et al.*, 2016). However, it is not yet clear whether rumen microbes can detoxify the toxins in *L. camara* or adapt to it. Literature has also claimed that consuming *L. camara* leafy biomass can only become detrimental when an animal consumes more than 1% of its metabolic body weight (Ghisalberti, 2000). While consumption of *L. camara* has been confirmed, it is not clear whether animal performance is enhanced or compromised. Considering these conflicting results from researchers, some pointing out that *L. camara* is poisonous, and others regarding it as a potential protein supplement, it is imperative to assess the effect of feeding it to ruminants. To settle these conflicting results and questions, a feeding trial was conducted to assess whether *L. camara* causes variation in animal performance when fed at different inclusions of leaf hay to the animals. Therefore, the study hypothesised that different *L. camara* leaf hay inclusion levels in goats' diets may cause variations in rumen microbial protein production, apparent digestibility, nitrogen balance and the overall performance of the animal. The study objectives were to assess the effects of *L. camara* on the performance, digestibility, nitrogen balance and microbial protein synthesis in Small East Africa Goat Breeds.

## MATERIALS AND METHODS

### Study site

Red *L. camara* variety leaves were harvested from the University of Zimbabwe, Faculty of Veterinary Science animal paddocks in Harare in June 2016. The harvest was done in Harare because the Harare *L. camara* leafy materials had the highest concentrations of extractable total phenolics (Gusha *et al.*, 2016). The University of Zimbabwe lies 17º 49' S and 31º 03' E to an altitude of between 1200 to 1550 m. The maximum monthly mean temperature during the wet season is around 28º C while dry season temperatures fall to below 7º C in June. The feeding trial was carried out at the Bioassay laboratory in the Department of Animal Science at the University of Zimbabwe.

### Feed formulation and experimental design

The leaves were shade dried for ten days until a constant dry matter was obtained. Two hundred grams of leafy hay of *L. camara* was ground before a chemical analysis was done. Results of the chemical analysis were used during the formulation of diets. *Lantana camara* leaf hay was milled using a hammer mill without a screen or sieve. *Lantana camara* leaf hay and soya bean were used as protein ingredients, with *L. camara* replacing soya bean at 5%, 10%, 15%, 20%, and 25% of formulated supplementary feed (Table 1). The formulated diets were iso-nitrogenous and iso-energetic. Veld hay and water were offered *ad-libitum.* The control diet was purchased from a feed manufacturing company but was analysed for chemical composition as was done with the formulated feed.

### Experimental design and animal management

The experiment was approved by the Faculty of Veterinary Science Experimental Research Ethics Committee. A total of eighteen, six to ten months old castrated goats with a mean± (SD) body weight of 13.6 kg (±4.9) were randomly assigned to the six treatment diets in a completely randomised design. The Ethics Committee recommended the use of few animals to minimise risk exposure since the shrub was claimed to be poisonous. The six treatments were commercially bought goat meal, five inclusion levels (5%LC, 10%LC, 15%LC, 20%LC and 25%LC). The castrated goats were of the Small East African Goat Breed. Before the study, the kids were dosed for internal parasites using Valbazen® (Albendazole) and dipping was done monthly with Triatix® (Amitraz) spray. Each goat was housed individually in metabolism cages to allow for individual feeding and collection of urine and faeces. Each goat was given the 0.3kg treatment diet at 0800hours and 0.8 kg of a basal diet of veld hay was given at 1200 hours for 21 days. The first 11 days were used as an adaptation period where there was no data collection. During the ten days of data collection, total faeces, urine and refusal samples were collected and weighed. Ten percent faecal samples were taken and stored in a cold room at 4°C before being analysed for dry matter, organic matter, and nitrogen. Urine was collected in buckets containing 100 ml of 1% sulphuric acid v/v to keep the pH below 3 for purine derivatives preservation and to minimise loss of nitrogen. Ten percent of the collected urine was frozen pending analysis for allantoin and N. The urine samples were filtered through surgical gauze and stored at −20°C.

**Table 1. The proportion of ingredients in kg used in formulating the treatment diets for the experiment on the effects of feeding *Lantana camara* on health and goat performance.**

| Ingredient | Treatment diets (LC inclusion levels) | | | | |
|---|---|---|---|---|---|
| | 5% LC | 10% LC | 15% LC | 20% LC | 25% LC |
| Maize | 27.2 | 28.0 | 25.4 | 25.4 | 23.2 |
| Soya cake | 4.8 | 4.0 | 3.4 | 2.6 | 2.0 |
| *L. camara* leaves | 2.0 | 4.0 | 6.0 | 8.0 | 10.0 |
| Molasses | 4.0 | 2.0 | 3.2 | 2.0 | 2.8 |
| Mineral premix | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Salt | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |

Note LC: represent *Lantana camara*.

**Chemical composition analysis**

Dry matter (DM), organic matter (OM), ash, calcium, and phosphorus of all the samples including goat feed, 5% LC, 10% LC, 15% LC, 20% LC 25% LC, veld hay, faeces, and refusals were determined according to the Association of Official Analytical Chemists (AOAC 1990a). The samples were then ground through a 1 mm sieve and analysed for nitrogen (N) according to AOAC, (1990b: #984.13). The determination of ash-free neutral detergent fibre (NDFom) was performed without sodium sulphite and expressed as residual ash according to Van Soest et al., (1991) while the ash-free acid detergent fibre (ADFom) was determined and expressed as residual of ash according to AOAC (1990c; #973.18). The extraction of the phenolic compounds was done by using 70% aqueous acetone solution. Total extractable phenolics (TEPH) were determined using the procedures of the Folin Ciocalteu method as described by Makkar (2003), while, extractable condensed tannins were assayed using the butanol-HCl method (Porter et al., 1986; Terrill et al., 1992). The concentrations of the total phenols were calculated using the regression equation of the tannic acid standard (Makkar, 2003). The urine was diluted with 8 litres of distilled water to reduce the concentration of purine derivatives. Urine samples were analysed for allantoin using the spectrophotometric method outlined in the IAEA technical document (IAEA-TECDOC-945; IAEA, 1997). Digestible organic matter fermented in the rumen (DOMR) was assumed to be digestible organic matter multiplied by 0.65 (Masama et al., 1997). Microbial protein yield was then calculated as 32 g N/kg DOMR.

**Calculations of feed efficiency parameters**

**Nitrogen retention**

Nitrogen retention was computed by subtracting total nitrogen output (faecal N [FN] and urinary N [UN] losses) from dietary N intake (NI).

Nitrogen retention ($gd^{-1}$) = NI − (FN + UN) .. (1)

Apparent Nitrogen digestibility ($gd^{-1}$) = NI − (FN + UN)/NI × 100............................................. (2)

Digestible organic matter intake (DOMI) was computed by subtracting faecal organic matter from the organic matter (OM) intake.

DOMI ($gd^{-1}$) = OM intake – faecal OM............ (3)

Metabolisable energy (ME) intake and DOMR were calculated from the DOMI content according to AFRC (1993):

ME intake (MJ $d^{-1}$) = 0.0157 × DOMI............. (4)

DOMR ($gd^{-1}$) = 0.65 × DOMI…...................... (5)

**Microbial protein yield**

Daily urinary purine derivatives and allantoin excretion were used to calculate the microbial protein yield using the equations of Chen and Gomes (1992) and IAEA (1997):

$Y = 0.84X + (0.15W^{0.75}e^{-0.25X})$ ......................... (6)

Where;

$Y$ = purine derivative excretion in urine (mmol $d^{-1}$) and; $X$ = concentration of microbial purines absorbed after duodenal and intestinal digestion (mmol $d^{-1}$).

Newton–Raphson iterative process was performed in calculating $X$ until it approaches a constant value (Chen and Gomes, 1992). $W^{0.75}$ represents the metabolic body weight (kg) of the animal.

Microbial nitrogen yield (MNY) (g $d^{-1}$) = $X$*70/ (0.83*0.116*1 000) = 0.727$X$........................ (7)

Where:

70 is a constant for the nitrogen content of purines (mg N $mmol^{-1}$), 0.83 is the average digestibility of mixed microbial purines based on observations reported in the literature (Chen and Gomes, 1992), 0.116 is the proportion of purine nitrogen in the total microbial nitrogen of mixed rumen microbes, and 1/1 000 is to convert the estimate from milligrams to grams per day.

Digestible microbial true protein (DMTP), Microbial true protein (MTP) and efficiency of microbial nitrogen supply ($E_{mns}$) were computed following AFRC (1993).

MTP ($gd^{-1}$) = 0.80 × MNY × 6.25................... (8)

Digestible microbial true protein ($gd^{-1}$) = 0.85 × MTP………………………………………..... (9)

Emns (g $kg^{-1}$ DOMR) = MNY/DOMR........... (10)

**Statistical analyses**

Analysis of variance was carried out on the data using the PROC GLM procedure of SAS version 9 (SAS, 2010) fitting the following model:

$Y^{ijk} = \mu + T^{i} + \varepsilon^{ijk}$

Where:
$Y^{ijk}$ = Response variable being (Chemical composition, live weight changes, Nitrogen Retention, Digestibility, DOMR and Allantoin excretion); µ = Overall mean common to all observations; $T^{i}$ = Effect of the ith treatment diet; (Goat feed, 5% LC, 10% LC, 15% LC, 20% LC and 25% LC); εij = Random residual error.

The general linear model procedure above shown was used to determine the effect of treatment diets on chemical composition, live weight changes, digestibility, nitrogen retention, microbial protein production, and haematology parameters. All quantitative response variables were tested for normality using the Shapiro-Wilk's test and $\log^{10}$ transformed where necessary before statistical analyses using SAS proc mixed procedure while qualitative data were analysed using SAS proc freq procedure.

## RESULTS

### Chemical composition of the treatment diets

The N level was 2.52±0.03% of DM/kg while GE was 13.94 ±0.78 Mj/kg of DM of the experimental diet. The diet DM content ranged between 81.4 to 89.07 % and TEPH ranged from 0.38 to 0.80 with 20% LC having the highest total extractable phenolic compounds (P<0.05). The commercial goat meal had TEPH, which is an indication that most feed ingredient contains some secondary plant metabolites as shown in Table 2. When the statistical analysis was performed 20% LC diet had a significantly higher TEPH content than the other diets. Secondly, the DM content was significantly different, with commercial goat feed having a higher value compared to the formulated diets.

**Table 2. Chemical composition of diets with 5, 10, 15, 20 and 25% *Lantana camara* inclusion level, goat feed and veld hay.**

| | VH | 5% LC | 10% LC | 15% LC | 20% LC | 25% LC | GF | LSD |
|---|---|---|---|---|---|---|---|---|
| DM (%) | $90.43^{a}$ | $81.4^{c}$ | $83.78^{bc}$ | $83.67^{bc}$ | $86.42^{ab}$ | $85^{ab}$ | $89.07^{a}$ | 2.64 |
| ASH (%DM) | $7.05^{ab}$ | $4.6^{bc}$ | $4.99^{bc}$ | $4.99^{bc}$ | $6.3^{ab}$ | $8.19^{a}$ | $6.49^{ab}$ | 1.35 |
| N (% DM) | $0.65^{c}$ | $2.56^{a}$ | $2.5^{a}$ | $2.51^{a}$ | $2.52^{a}$ | $2.54^{a}$ | $2.49^{a}$ | 0.03 |
| GE (Mj/kgDM) | $15.93^{a}$ | $13.34^{ab}$ | $12.81^{c}$ | $13.71^{a}$ | $14.81^{a}$ | $14.42^{a}$ | $14.57^{a}$ | 0.78 |
| NDFom (%DM) | $40.78^{a}$ | $11.97^{c}$ | $19.73^{bc}$ | $20.04^{bc}$ | $17.46^{bc}$ | $16.49^{bc}$ | $24.23^{b}$ | 4.11 |
| ADFom (%DM) | $36.17^{a}$ | $4.88^{c}$ | $6.28^{bc}$ | $8.79^{b}$ | $9.94^{b}$ | $8.93^{b}$ | $8.46^{b}$ | 0.63 |
| TEPH (mg/kgDM) | $0.52^{b}$ | $0.24^{c}$ | $0.46^{b}$ | $0.56^{b}$ | $0.8^{a}$ | $0.57^{b}$ | $0.38^{b}$ | 0.19 |

DM= dry matter, N = nitrogen, GE = gross energy, NDF = neutral detergent fibre, ADF = acid detergent fibre, TEPH= Total extractable phenolics, LC= *Lantana camara*, GF = Goat feed, VH = Veld hay, SDEV= Least Significant Difference
Different $^{abc}$ superscripts in the row indicate a significant difference between treatments.

**Dry matter intake and apparent digestibility**

Goats fed on 10%LC consumed significantly lower quantities of hay than 5%LC but were not significantly different from goat feed (GF), 15%LC, 20%LC and 25%LC (Table 3). The amount of GF and 5%LC diets consumed were not significantly different. The 5%LC and GF intake were higher and significantly different from 10% LC. Goats on 10%LC consumed significantly higher total dry matter intake than those on treatments 15%LC, 20%LC and 25%LC. Significantly more dry matter faecal excretion (g/day) was observed on goats supplemented with GF than the other five treatment diets. Total faecal output on 5%LC and 10%LC treatments were significantly different from 15%LC, 20%LC, and 25%LC. Significantly higher DOMI was observed on 5%LC, followed by GF and 10%LC. Very low DOMI was observed on goats given 25%LC which was only 187.8 grams per day. There was significantly higher metabolisable energy intake by goats at 10%LC than those in the other treatments. No significant difference in ME intake was observed in goats given GF, 5%LC, 15%LC and 20%LC which significantly consumed higher ME than goats in 25%LC treatment. Apparent digestibility coefficient values were significantly different with goats given 5%LC having higher value but not significantly different from 10%LC, 15%LC, 20%LC.

The effects of feeding graded *Lantana camara* hay on nitrogen intake and retention goats given GF and 5%LC consumed significantly higher N in feed than the goats on other treatments (Table 4). The highest total N loss was observed in the group of goats given 10%LC, GF and 5%LC. Significantly higher N retention values were observed in groups fed on 5%LC and GF compared to the other groups (Table 4).

The effects of graded levels of *L. camara* hay on excretion of allantoin and microbial protein production. The highest volume of allantoin was recorded in the group fed on 5% LC and the lowest was on 25%LC (Table 5). Significantly highest MTP was observed in groups fed 5% inclusion level of *L. camara* than recorded with GF. Microbial protein production followed the same trend. Significantly high DMTP value was recorded in 5% LC followed by GF and 10% LC and the lowest was on 25% LC. The opposite was recorded on efficiency in microbial nitrogen supply per DOMR which was observed to be significantly higher with 25% LC and the least in GF (Table 5).

## DISCUSSION

**Chemical composition of the experimental diets**

All the diets used in the study met the maintenance and fattening requirements for goats, which is recommended to be above 1.28 percent

**Table 3. Average dry matter intake, dry and organic faecal elimination, digestible organic matter, metabolisable energy intake ($gd^{-1}$) and apparent digestibility in goats given graded levels of *Lantana camara* hay, commercial goat feed and veld hay.**

| | Treatment diets | | | | | | |
|---|---|---|---|---|---|---|---|
| | GF | 5% LC | 10% LC | 15% LC | 20% LC | 25% LC | LSD |
| Basal diet (Veld hay intake) (g d−1) | $236.8^{ab}$ | $266.5^{a}$ | $220.8^{b}$ | $232.8^{ab}$ | $254.0^{ab}$ | $230.9^{ab}$ | 43.41 |
| Experimental feed intake (g d−1) | $368.8^{a}$ | $350.5^{a}$ | $283.7^{b}$ | $151.5^{c}$ | $151.5^{c}$ | $124.9^{c}$ | 29.96 |
| Total dry matter intake (g d−1) | $605.6^{a}$ | $617.0^{a}$ | $516.5^{b}$ | $405.6^{c}$ | $382.5^{cd}$ | $344.8^{d}$ | 55.86 |
| Dry matter faecal elimination (g d−1) | $228.2^{a}$ | $180.2^{b}$ | $165.4^{b}$ | $135.8^{c}$ | $133.2^{c}$ | $126.9^{c}$ | 25.21 |
| Organic matter faecal elimination | $213.2^{a}$ | $168.3^{b}$ | $154.5^{b}$ | $126.8^{c}$ | $124.4^{c}$ | $118.5^{c}$ | 23.55 |
| Organic matter intake (g d−1) | $540.5^{a}$ | $554.5^{a}$ | $464.9^{b}$ | $360.2^{c}$ | $340.6^{cd}$ | $306.3^{d}$ | 49.13 |
| Digestible organic matter intake (g d−1) | $212.0^{b}$ | $386.2^{a}$ | $309.5^{b}$ | $233.4^{c}$ | $216.2^{cd}$ | $187.8^{d}$ | 41.24 |
| Metabolisable energy intake (MJ d−1) | $5.14^{b}$ | $6.06^{a}$ | $4.85^{b}$ | $3.66^{c}$ | $3.40^{cd}$ | $2.95^{d}$ | 0.56 |
| Apparent digestibility coefficient: | | | | | | | |
| Dry matter digestibility | $0.62^{c}$ | $0.71^{a}$ | $0.68^{ab}$ | $0.66^{ab}$ | $0.65^{ab}$ | $0.63^{bc}$ | 0.06 |
| Organic matter digestibility | $0.61^{c}$ | $0.70^{a}$ | $0.67^{ab}$ | $0.65^{abc}$ | $0.63^{bc}$ | $0.61^{bc}$ | 0.06 |

LC=*Lantana camara*. LSD = Least Significant Difference

[abcd] Means in the same row followed by different superscript letters are significantly different ($P < 0.05$),

**Table 4. Nitrogen intake and retention (g/d$^{-1}$) in goats given graded levels of *Lantana camara* leaf hay, commercial goat meal feed and a basal diet of Veld hay.**

| Parameter | Treatment diets | | | | | | |
|---|---|---|---|---|---|---|---|
| | GF | 5% LC | 10% LC | 15% LC | 20% LC | 25% LC | LSD |
| Nitrogen intake | 12.00$^{a}$ | 11.79$^{a}$ | 9.78$^{b}$ | 6.76$^{c}$ | 6.40$^{c}$ | 5.52$^{d}$ | 0.91 |
| Nitrogen in faeces | 3.25$^{a}$ | 2.61$^{ab}$ | 2.44$^{ab}$ | 1.97$^{b}$ | 1.81$^{b}$ | 1.73$^{b}$ | 0.85 |
| Nitrogen in urine | 2.3$^{b}$ | 2.46$^{b}$ | 3.64$^{a}$ | 1.33$^{c}$ | 1.34$^{c}$ | 0.99$^{c}$ | 0.63 |
| Total nitrogen in faeces and urine | 5.56$^{a}$ | 5.07$^{a}$ | 6.08$^{a}$ | 3.30$^{b}$ | 3.15$^{b}$ | 2.72$^{b}$ | 1.32 |
| Nitrogen retention | 6.43$^{a}$ | 6.62$^{a}$ | 3.60$^{b}$ | 3.36$^{b}$ | 3.25$^{b}$ | 2.70$^{b}$ | 1.63 |

LC = *Lantana camara*, GF = commercial goat feed, LSD=Least Significant Difference

$^{abcd}$ Means in the same row followed by different superscript letters are significantly different ($P$ < 0.05),

**Table 5. Excretion of purine derivatives and microbial protein production by goats given graded levels of *Lantana camara* hay, commercial goat feed and veld hay.**

| | Treatment diets | | | | | | |
|---|---|---|---|---|---|---|---|
| | GF | 5% LC | 10% LC | 15% LC | 20% LC | 25% LC | LSD |
| Allantoin (mmol d$^{-1}$) | 9.34$^{b}$ | 11.95$^{a}$ | 9.60$^{b}$ | 7.59$^{c}$ | 7.07$^{c}$ | 6.26$^{c}$ | 1.97 |
| Microbial nitrogen yield (MNY) (g d$^{-1}$) | 6.79$^{b}$ | 8.69$^{a}$ | 7.01$^{b}$ | 5.52$^{c}$ | 5.14$^{c}$ | 4.53$^{c}$ | 1.69 |
| Microbial true protein (MTP) (g d$^{-1}$) | 34.0$^{b}$ | 43.5$^{a}$ | 35.04$^{b}$ | 27.6$^{c}$ | 25.7$^{c}$ | 22.7$^{c}$ | 9.14 |
| Digestible Microbial true protein (DMTP) (g d$^{-1}$) | 28.9$^{b}$ | 36.9$^{a}$ | 29.8$^{b}$ | 23.4$^{c}$ | 21.9$^{c}$ | 19.3$^{c}$ | 8.21 |
| Fermentable organic matter in the rumen (g d$^{-1}$) | 212.0$^{b}$ | 251.0$^{a}$ | 201.0$^{b}$ | 152.0$^{c}$ | 141.0$^{cd}$ | 122.0$^{d}$ | 25.10 |
| Emn$_s$ (g kg$^{-1}$DOMR) | 31.9$^{c}$ | 34.7$^{b}$ | 34.8$^{b}$ | 36.4$^{a}$ | 36.6$^{a}$ | 37.9$^{a}$ | 8.25 |

LC = *Lantana camara and* GF = commercial goat feed. $E_{mns}$= efficiency of microbial nitrogen synthesis (AFRC 1993), DOMR = Digestible organic matter in the rumen LSD= Least Significant Difference

$^{abcd}$ Means in the same row followed by different superscript letters are significantly different ($P$ < 0.05).

nitrogen per kg DM (AFRC, 1993; Mokoboki *et al.,* 2005; Mapiye *et al.,* 2010). The level of nitrogen was 2.4 % per kilogram of DM, which was also above the recommended level hence it was adequate to support the normal growth and production levels such as growth and fattening. In ruminants, feeds with lower CP than 1.12 percent nitrogen per kilogram DM are known to reduce voluntary feed intake resulting in stunted growth and sub-optimal reproduction performance (Matizha *et al.,* 1997; Ngongoni *et al.,* 2007; Gusha *et al.,* 2014). The levels of crude protein recorded in this study support the utilisation of this invasive plant species in livestock nutrition.

The levels of TEPH were lower than those found in *Acacia angustissima* (8.1%) (Ncube *et al.,* 2017), *Calliandra calothyrsus* (10.8%) and *Leucaena leucocephala* (7.6%) (Gusha *et al.,* 2013) which are browse legume trees that have successfully been incorporated into livestock feeding systems as protein supplementary feed for poor roughage diets in communal areas and small-scale livestock production systems (Katsande *et al.,* 2016, Ncube *et al.,* 2017). However, improved performance of goats and cattle when given as supplements to animals feeding on poor roughage grass straws in Zaka and at Makoholi Research Institute in Zimbabwe (Gusha *et al.,* 2015, 2016). Based on the level of TEPH obtained in these formulated diets, using these diets to feed animals should not cause detrimental effects but beneficial to the animals' health. The concentration of TEPH per unit DM was also lower than the values measured in *L. camara* hay (68 grams per kg/DM) harvested in Harare (Gusha *et al.,* 2016), these results show the importance of mixing it with other feed ingredients before feeding as it dilutes the concentration of anti-nutritional factors and other secondary plant metabolites. The concentrations become lower than the threshold of toxicity but producing a diet sufficient to meet the nutritional needs of the animal.

**The effects of feeding graded levels of *L. camara* leaf hay on dry matter intake and apparent digestibility**

High ADFom and low nitrogen diets are associated with reduced voluntary feed intake because of the slow rate of rumen degradation of feed. The average daily dry matter intake was above the minimum recommended of three percentage of the animal's metabolic body weight (Mokoboki *et al.,* 2005; Salem *et al.,* 2007; Nasri *et al.,* 2011). However, animals fed on commercial formulated diets and those that were given diets with ≤10% *L. camara* leaf hay consumed more than what the goats in treatment with ≥15% *L. camara* leaf hay inclusion rate consumed. It was observed during the study that large quantities of *Lantana camara* leaf hay produced an unpleasant scent. This could explain the low dry matter intake observed with the increase in *L. camara* leaf hay inclusion beyond the fifteen percent in a diet. This observation support what was observed when *Gliricidium sepium* with an unpleasant smell was feed to goats (Gusha et al., 2014). These results suggest that *L. camara* leaf hay low palatability and acceptability if inclusion levels are greater or equal to fifteen percent. Diets with higher inclusion levels of *L. camara* leaf hay seems to have a stronger smell that influenced a declined in dry matter intake. The variable nature of the secondary chemistry of plants is the basis for differential use within and among plant species. (Shimada, 2006; Rogosic *et al.,* 2008; Estell, 2010). There is a varying preference for *L. camara* varieties by animals hence differential consumption pattern of the plant in different locations in Zimbabwe as reported by farmers and observed by Gusha *et al.* (2016). Preference of browse intake is negatively affected by a wide array of secondary metabolites present in the plants (Salem *et al.,* 2006). In particular, intake can be affected by the concentration of phenolic compounds and tannins (Estell, 2010), however in this study, the level of total extractable phenolic recorded could not suggest that. Villalba *et al.* (2002); Provenza *et al.* (2003); Swihart *et al.* (2009); Feng *et al.* (2009) and Kambashi *et al.* (2014) reported that the concentration of condensed tannins, total phenolic, saponins and essential oils in forage are good indicators of intake patterns in sheep and goats. However, the reported observation could not be ascertained in this study as we did not identify individual secondary plant metabolites levels.

The apparent organic matter digestibility coefficient was above 60% of kg dry matter. The observed high apparent organic matter digestibility coefficients give the impression that these diets could meet the nutrient requirement for ruminants. The results are consistent with the results reported by Osuga *et al.* (2008) that *L. camara* is highly degradable. It is high in non-structural carbohydrates and low in ADF (less than 31DM) as reported in Osuga *et al.,* (2008) and Gusha *et al.,* (2016). Highly fermentable carbohydrates and crude protein in a diet promote microbial multiplication and growth resulting in a high yield of microbial protein. If the highly fermentable metabolisable carbohydrates are coupled with highly digestible nitrogen also found in these diets, more efficiency in microbial protein production is expected. Increasing substrates for rumen microbial protein production increases rumen degradation rate and the release of nutrients that promote optimum growth and productivity. Therefore, animals under such feeding regimes and on these formulated diets with fifteen percent or lower of *L. camara* leaf hay inclusion are expected to perform positively.

In addition, a very high apparent N digestibility coefficient was obtained. However, it should be noted that this measurement is sometimes not a very useful parameter of measuring protein digestibility especially in ruminants. It does not reflect the true undigested dietary nitrogen since some of the nitrogen is undigested microbial protein, sloughed-off cells of the gut lining and enzymes secreted into the digestive tract (Kida *et al.,* 2009; Kozloski *et al.,* 2014). Gusha *et al.* (2015) reported that animals given poor quality grass straws incur negative nitrogen retention due to abrasion of the epithelial wall. They may be an increase in metabolic faecal nitrogen from enzymes, sloughed-off cells from the digestive tract and microbial residues hence relying on this measurement especially the apparent N digestibility coefficient, may give a false indicator of what the animals may be getting (Kozloski *et al.,* 2014). It is believed that grazing animals use nutritional wisdom when eating highly fibrous diets and, in most cases, may not eat these standing hays straws of poor quality in order not to incur a negative energy and nitrogen balance (Gusha et al., 2016). To supply the rumen microbes with ammonia, the animals may have to increase the breakdown of their own muscle or turnover of body protein and this is an unnecessary cost incurred by animals grazing or feeding on straws and poor-quality fibrous diets.

### The effects of feeding graded levels of *L. camara* leaf hay on nitrogen intake and retention

Higher N intakes were observed with diets such as goat feed and five percent *L. camara*. However, the opposite was observed with regards to N retention with diets with 10% of *L. camara* inclusion or more. This could be because that the lower the DM intake or rumen-fill, the longer the rumen residence time for the feed to be degraded by microbes (Ngongoni *et al.,* 2007) and the higher the digestibility coefficient. In addition, animals feeding on forages with plant secondary metabolites evolve a variety of intertwined mechanisms to cope with the consumption of these compounds (Estell, 2010). Some of the coping strategies range from physiological to behavioural mechanisms which include regulation of intake below a critical threshold, cautious sampling, altering size and pattern of feeding bout, diet switching, consuming diverse and complementary diets (Estell, 2010). The results show that the animals regulated their daily dry matter and N intake probably to reduce the concentration of unwanted substances entering the rumen as low intake levels were recorded on diets with higher levels of *L. camara*.

### The effects of feeding graded *L. camara* leaf hay on excretion of allantoin and microbial protein production

Allantoin values ranging between 6.26 and 11.95 mmol per day in 25% and 5% *L. camara* inclusion rate respectively, were observed which were higher than the values reported by Katsande *et al.* (2015). In sub primate mammals, purine metabolism produces uric acid, which is oxidised to allantoin before being excreted in urine (Chen and Gomes, 1992). Therefore, the level of allantoin or total urinary purine derivatives ( namely allantoin, uric acid, xanthine, hypoxanthine and hypuric acid are used to estimate microbial protein production (MPP). Allantoin has been used more often to estimate microbial protein production as it constitutes 85% of the total urinary purine derivatives and there was no significant difference in MPP estimates when allantoin and total protein production were used to estimate total microbial protein production. Diets with *L. camara* recorded high levels of MPP and the process of defaunation could not be ruled out as a possible reason why there were significantly higher MPP and efficiency of microbial nitrogen supply in groups of animals fed on diets with higher levels of *L. camara*. In animal feeding studies, where animals are fed with forages high in plant secondary metabolites, it has been reported that compounds such as phenolic compounds could be toxic to rumen cellulolytic bacteria (Pfister, 1999; Lauchbaugh *et al.,* 2001). Poisoning of rumen cellulolytic bacteria resulted in lowering fibre degradation in the rumen (Swihart *et al.,* 2009). However, the presence of saponins may cause defaunation of ruminal protozoa thus promoting an increase in microbial nitrogen flow from rumen as well as a decrease in methane gas production (Rogosic *et al.,* 2008; Estell, 2010; Pfister *et al.,* 2010). However, in this study, there is no evidence of reduced degradation and hence toxicity to rumen cellulolytic bacteria could be ruled out because of the very high apparent digestibility recorded.

## CONCLUSION

The study assessed the effects of feeding graded levels of *L. camara* leaf hay meal on the performance, digestibility, nitrogen balance and microbial protein synthesis in Small East Africa Breeds. The diets formulated with the inclusion of invasive *L. camara* leaf hay met the nutrient requirement of goats. In addition, *L. camara* leaf hay could be a protein source, this could be a strategy to lower the cost of protein supplements in goat production. Furthermore, voluntary feed intake was not affected in all the formulated diets and was above the minimum recommended of 3% of the animal's metabolic body weight. We, therefore, conclude that *L. camara* like most browse shrubs contains some TEPH which can limit their use in livestock production but inclusion levels of 5% can produce good quality ruminant feed supplements as demonstrated by the 5%LC diet in this experiment. *Lantana camara* can be conserved as hay and mixed with poor quality for dry season supplementary feeding. Therefore, this study recommends a maximum *L. camara* leaf hay inclusion level of 5% since diets with above level could negatively affect dry matter intake and N retention and microbial protein production. The inclusion of this invasive plant species in goat diets could be used as a control strategy and limit its spread in rangelands. This will in turn counter the current threats posed by *L. camara* level spread such as lowering grass biomass for grazing livestock through competition for nutrients, water and light.

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