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ORIGINAL RESEARCH ARTICLE

# Feed intake, digestibility, nitrogen utilization and ruminal fermentation characteristics of Red Sokoto goats fed concentrate partially replaced with *Piliostigma thonningii* foliage

**[*,1]Olafadehan O. A., [2]Okunade S. A., [1]Njidda A. A., [3]Adewumi M. K., [1]Sunday U. E and [1]Salihu S. O.**

*[1]Department of Animal Science, University of Abuja, Abuja*
*[2]Department of Animal Production Technology, Federal College of Wildlife Management, New Bussa, Nigeria*
*[3]Department of Animal Science, University of Ibadan, Ibadan*
*Corresponding author: oaolafadehan@yahoo.com

**ABSTRACT**
***Fifteen 9-month-old, Red Sokoto male goats (13.6±0.68 kg) fed threshed sorghum top basal diet, were used to study the nutritive value of Piliostigma thonningii (PT) foliage as a replacement for concentrate. There were three diets: supplementary concentrate fed at 5% of BW; 25 and 50% of the concentrate replaced with PT leaves, respectively. Concentrate replacement with PT linearly increased intakes of total DM (P = 0.02), organic matter (OM), total carbohydrate (TC), fibre fractions, cellulose, condensed tannins (CTs) (P < 0.0001), digestible organic matter (DOM) (P = 0.034), energy (P = 0.031), digestibilities of hemicellulose (HC) (P = 0.006) and cellulose (P < 0.0001), digestible OM fermented in the rumen (DOMR), volatile fatty acid (VFA) and microbial protein synthesis (MPS) (P = 0.034), and digestible crude protein (DCP) (P = 0.029). Diets had both linear and quadratic effects on digestibilities of non-fibre carbohydrate (NFC) (P < 0.0001), neutral detergent fibre (NDF) (L:P = 0.01; Q:P = 0.012), acid detergent fibre (ADF) (L:P = 0.026; Q:P = 0.007) and lignin (L:P = 0.008; Q:P < 0.0001). N retention had a quadratic trend (Q:P = 0.037). Lower intakes of total DM (P = 0.016), OM (P = 0.021), TC (P = 0.009), fibre fractions, cellulose and CTs (P = 0.0001), digestibilities of NFC (P = 0.003), NDF (P = 0.002), ADF (P = 0.004), lignin (P = 0.001), HC (P = 0.006), cellulose (P = 0.011) and energy (P = 0.018), DOM intake, DOMR and MPS (P = 0.002), VFA (P = 0.025) and pH (P = 0.001) were observed in control vs. PT. However, NFC digestibility and urinary N (P = 0.003), and DCP (P = 0.043) were higher for control vs. PT. Supplemental concentrate can be replaced with PT foliage without detrimental effects on feed intake, digestibility, N utilization and ruminal fermentation.***

**Keywords:** Concentrate replacement, Condensed tannins, Goat, Nutritive value, *Piliostigma thonningii*

## INTRODUCTION

Food shortage is becoming critical, particularly in developing countries, due to ever-increasing human population. In recent years, the prices of conventional livestock feeds have drastically soared as a result of increased demand. Increase in price of concentrates has encouraged nutritionists to search for cheaper, readily available, non-competing, and non-conventional alternative materials. Many attempts have been made (Okunade *et al*., 2014a; Olafadehan, 2013; Olafadehan *et al*., 2014a) to introduce unconventional new forages for ruminant feeding in an attempt to reduce production cost, improve livestock production and increase animal protein intake. Improved livestock production could be achieved through the use of high quality forage adapted to local conditions as well as feeding concentrate. Concentrate feeds promote rapid growth in ruminants (McDonald *et al*., 2002), reduce ruminal methane production and increase ruminal propionate production, thereby lowering energy losses and contributing to higher overall efficiency of utilization of dietary energy for body weight gain (Mandebvu and Galbraith, 1999). However, due to high cost of concentrates, there is the need to reduce their quantity in goat's diets so as to make production sustainable. This can be achieved by partially replacing concentrate with browse fodders but browse fodders should be used with caution because quite a number of them contain secondary metabolites. Feed intake and digestibility of forages are suppressed leading to limited animal performance caused by anti-nutritional factors, especially tannins present in the browse plants (Meissner and Paulsmeier, 1995). Therefore, limited quantity of tree leaves in animal feed is recommended to improve rumen function and productivity (Osakwe *et al*., 2004). *Piliostigma thonningii* (PT) is a leguminous plant belonging to the family Caesalpiniacea, a family that comprises trees, shrubs or very rarely scramblers. It is copiously available in savannah regions of Nigeria. The purpose of this study was to examine the feed intake, digestibility, nitrogen utilization and ruminal fermentation in Red Sokoto goats fed concentrate diet partially replaced with *Piliostigma thonningii* foliage**.**

## MATERIALS AND METHODS

### Animals and management

The experiment was conducted at the University of Abuja Teaching and Research Farm. The site (9°12' N and 7°11' E) is at 456 m altitude. The mean annual rainfall and temperature range from 1100 to 1600 mm and 25.8 to 35.1ºC, respectively. Fifteen intact Red Sokoto male goats (13.6±0.68 kg) at about 9 months of age were used. Goats were individually housed in slated floor metabolism cages (1.0 m × 1.2 m) and were treated with Ivermectin solution (1 ml/50 kg BW) against internal and external parasites and Oxytetracycline (1 ml) against bacterial infection. They were balanced for their body weight (BW) such that animals in each treatment group had similar initial BW. They were allowed two weeks adjustment to the metabolic cages before data collection and were fed with the experimental diets during the adjustment period. Pen cleaning was done twice a week. Feeding was twice daily.

### Diets and experimental design

The leaves of PT used for the study were at a mature stage and harvested from several stands in the university environment. A concentrate diet (maize, 25%; corn bran, 27%; dried brewers grains, 30%; groundnut cake, 12%; urea, 1%; salt, 2%; limestone, 2% and vitamin/mineral premix, 1%) replaced by PT leaves was formulated. Thus the dietary treatments were: 100% concentrate, 25% of concentrate replaced with an equal amount (DM basis) of PT leaves and 50% concentrate replaced with an equal amount (DM basis) of PT leaves. Goats were randomly assigned to one of three diets in a completely randomized design. Diets were fed at 5% BW of the animals while the basal diet, threshed sorghum top (TST), and water were provided *ad libitum*.

### Metabolism trial

The 2-week adjustment period was preceded by 7-day data collection. Voluntary feed intake was measured daily by recording feed offered and refused for each animal. Daily faecal and urinary output were collected and about 20% of the total collection was saved for each animal. The faecal samples were dried in a forced-air oven at 70 ˚C for 48 hours. The dried faecal and urinary samples of each goat were bulked over the 7-day collection period and sub-sampled. The oven-dried faecal subsamples were milled with a simple laboratory mill and stored in air tight bottles until they were required for analysis. The urinary samples were acidified by adding 2 ml of 10% $H_2SO_4$ to each sample to prevent loss of N and kept in a freezer until required for analysis.

### Rumen liquor collection

About 50 mL of rumen fluid samples per animal were collected before the morning feeding on the last day of the experiment by aspiration using stomach tube. Ruminal pH was immediately determined using a digital pH meter. The liquor was then strained through four layers of muslin cloth, kept in plastic containers into which a few drops of mercuric chloride were added to stop microbial activity and subsequently frozen pending analysis.

### Chemical analysis

Proximate composition of samples was determined as outlined by AOAC (1995). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin were analysed by the methods of Van Soest et al. (1991). The NDF was assayed without use of an alpha amylase but with sodium sulphite. Both NDF and ADF were expressed without residual ash. Concentrations of hemicellulose (HC) and cellulose were calculated as the difference between NDF and ADF and ADF and lignin, respectively. Condensed tannins (CTs) were determined by the methods of Makkar (2003). Rumen fluid was analysed for total N by Kjeldahl method (AOAC, 1995), $NH_3$-N (Fenner, 1965) and volatile fatty acids (VFA) (Erwin *et al*., 1961).

**Statistical analysis and calculations**

Data were subjected to the analysis of variance for a complete randomized design using SPSS Base 17 (SPSS software products, USA). Linear and quadratic effects were determined using polynomial orthogonal contrasts for equally spaced treatments. The CONTRAST statement in SPSS was used for treatment pair: Control versus *Piliostigma thonningii* (PT) (C vs. PT) Significant differences were declared if $P \leq 0.05$. Microbial protein synthesis was calculated using Chen and Gomez (1995) equation as follows:

Microbial N yield = 32 g/kg x DOMR (digestible organic matter fermented in the rumen)

**RESULTS**

Chemical composition of the basal diet, concentrate and Piliostigma fodder is presented in Table 1. Crude protein (CP), organic matter (OM), ether extract (EE), non-fibre carbohydrate (NFC) and hemicellulose (HC) were higher in concentrate relative to Piliostigma forage but total carbohydrate (TC), cellulose and fibre fractions were higher in the Piliostigma fodder. The basal diet is a typical low quality roughage with low CP and high fibre fractions. Both TST and Piliostigma forage were tannin-containing feeds; CTs of Piliostigma leaves were higher than that of TST.

**Table 1: Chemical composition (%) of the experimental diets**

| Item | Threshed sorghum top | *P. thonningii* | Concentrate |
|---|---|---|---|
| Dry matter | 93.58 | 94.88 | 93.62 |
| Crude protein | 7.21 | 15.83 | 18.60 |
| Organic matter | 87.19 | 90.86 | 93.59 |
| Total carbohydrate | 73.53 | 70.66 | 65.0 |
| NFC | 13.23 | 31.01 | 41.18 |
| Ether extract | 6.45 | 4.37 | 9.99 |
| Ash | 12.81 | 9.14 | 6.41 |
| Crude fibre | 35.04 | 30.08 | 24.74 |
| Neutral detergent fibre | 60.30 | 39.65 | 23.82 |
| Acid detergent fibre | 42.72 | 33.27 | 12.42 |
| Acid detergent lignin | 9.24 | 8.06 | 3.98 |
| Hemicellulose | 17.58 | 6.38 | 11.40 |
| Cellulose | 33.48 | 25.21 | 8.44 |
| Condensed tannins | 0.19 | 0.28 | - |

TC: Total carbohydrates, NFC: non-fibre carbohydrates were determined according to Sniffen *et al*. (1992): TC = 100 - (CP+EE+Ash); NFC = 100 - (NDF+CP+EE+Ash).

Piliostigma forage intake was higher (L:$P$ = 0.002) for 50% than 25% concentrate replacement (Table 2). Increased concentrate and TST intakes (L:$P$ < 0.0001; Q:$P$ < 0.0001) and (L:$P$ = 0.005; Q:$P$ = 0.005) respectively were observed with increasing level of concentrate replacement. Total DM, OM and TC intakes had positive linear ($P$ = 0.02), ($P$ = 0.029) and ($P$ = 0.009) responses. Diet effects on CP, NFC and hemicellulose intakes were not ($P$ > 0.05) significant. Intake of EE tended towards a negative linear significance ($P$ = 0.076) with animals fed the control diet having the higher value. Intakes of fibre fractions, cellulose and CTs increased linearly ($P$ < 0.0001) with increasing concentrate replacement level. There was a quadratic tendency for increased intakes of NDF ($P$ =

0.095), ADF ($P$ = 0.073), cellulose ($P$ = 0.063) and CTs ($P$ = 0.057) with increased forage level in the diets. Concentrate intake was higher ($P$ < 0.0001) for control diet relative to PT diets. Intakes of TST ($P$ = 0.001), total DM ($P$ = 0.016), OM ($P$ = 0.027), TC ($P$ = 0.009) and fibre fractions, cellulose and CTs ($P$ < 0.0001) were higher for the control than the forage based diets. Intakes of CP, NFC, EE and HC were similar ($P$ > 0.05) for C vs. PT (Table 2).

**Table 2: Dry matter and nutrient intakes of experimental goats**

| Intake (g/d) | Concentrate replacement level | | | SEM | *P*-value | | |
|---|---|---|---|---|---|---|---|
| | 0% | 25% | 50% | | Linear | Quadratic | C vs. PT |
| F:C:T | 0:87:13 | 24:57:19 | 41:43:16 | - | | | |
| Forage | - | 98.98 | 175.33 | 10.94 | 0.002 | - | - |
| Concentrate | 315.69 | 236.57 | 183.79 | 14.5 | < 0.0001 | <0.0001 | <0.0001 |
| TSH | 48.74 | 78.99 | 71.17 | 5.18 | 0.005 | 0.005 | 0.001 |
| Total | 364.43 | 414.54 | 430.29 | 20.9 | 0.02 | 0.376 | 0.016 |
| CP | 62.23 | 65.36 | 67.07 | 3.49 | 0.215 | 0.822 | 0.236 |
| OM | 337.96 | 380.21 | 393.37 | 19.35 | 0.029 | 0.419 | 0.027 |
| TC | 241.04 | 281.79 | 296.67 | 14.33 | 0.009 | 0.321 | 0.009 |
| NFC | 136.45 | 138.56 | 139.47 | 7.44 | 0.699 | 0.929 | 0.704 |
| EE | 34.68 | 33.73 | 30.61 | 1.90 | 0.076 | 0.533 | 0.178 |
| NDF | 104.59 | 143.22 | 156.21 | 7.48 | <0.0001 | 0.095 | <0.0001 |
| ADF | 60.03 | 96.06 | 111.56 | 5.45 | <0.0001 | 0.073 | <0.0001 |
| Lignin | 16.85 | 24.69 | 28.02 | 1.37 | <0.0001 | 0.107 | <0.0001 |
| HC | 44.56 | 47.17 | 44.65 | 2.17 | 0.97 | 0.223 | 0.502 |
| Cellulose | 42.96 | 71.36 | 83.54 | 4.12 | <0.0001 | 0.063 | <0.0001 |
| CT | 0.09 | 0.43 | 0.63 | 0.04 | <0.0001 | 0.057 | <0.0001 |

F:C:T: forage: concentrate: threshed sorghum top ratio; TST: threshed sorghum top; CP: crude protein; OM: organic matter; EE: ether extract; TC: total carbohydrate; NFC: non-fibre carbohydrate; NDF: neutral detergent fibre; ADF: acid detergent fibre; HC: hemicellulose; CT: condensed tannins; C vs. PT: control diet versus Piliostigma diets

**Table 3: Apparent digestibility of dry matter and nutrients (%) in the experimental goats**

| Parameter | Concentrate replacement level | | | SEM | *P*-value | | |
|---|---|---|---|---|---|---|---|
| | 0% | 25% | 50% | | Linear | Quadratic | C vs. PT |
| Dry matter | 64.58 | 68.11 | 67.41 | 2.66 | 0.329 | 0.394 | 0.217 |
| Crude protein | 68.42 | 68.31 | 64.01 | 3.73 | 0.281 | 0.54 | 0.59 |
| Organic matter | 66.53 | 71.03 | 68.80 | 1.80 | 0.256 | 0.075 | 0.074 |
| Ether extract | 62.48 | 61.51 | 57.23 | 3.51 | 0.188 | 0.61 | 0.348 |
| TC | 63.04 | 69.42 | 66.45 | 2.32 | 0.191 | 0.059 | 0.051 |
| NFC | 69.96 | 70.52 | 66.54 | 0.34 | <0.0001 | <0.0001 | 0.003 |
| NDF | 51.24 | 59.17 | 57.23 | 1.60 | 0.01 | 0.012 | 0.002 |
| ADF | 45.03 | 55.44 | 51.15 | 2.09 | 0.026 | 0.007 | 0.004 |
| Lignin | 26.04 | 37.62 | 31.71 | 1.44 | 0.008 | <0.0001 | <0.0001 |
| Hemicellulose | 58.87 | 65.42 | 67.34 | 1.49 | 0.006 | 0.243 | 0.006 |
| Cellulose | 59.96 | 66.25 | 68.56 | 2.39 | 0.011 | 0.373 | 0.011 |

TC: total carbohydrate; NFC: non-fibre carbohydrate; NDF: neutral detergent fibre; ADF: acid detergent fibre; C vs. PT: control diet versus Piliostigma diets.

Apparent digestibilities of DM, CP and EE were marginally ($P$ > 0.05) affected by diets (Table 3). Digestibility of NFC was linearly and quadratically significant ($P$ < 0.0001 for L and Q). Treatment effects on digestibilities of NFC (L:$P$ = 0.01; Q:$P$ = 0.012), NDF (L:$P$ = 0.026; Q: $P$ = 0.007), and ADF and lignin (L:$P$ = 0.008; Q:$P$ < 0.0001) were linear and quadratic. Digestibilities of HC ($P$ = 0.006) and cellulose ($P$ = 0.011) increased linearly, though OM and TC digestibilities showed quadratic tendencies ($P$ = 0.075) and ($P$ = 0.059) respectively. Digestibilities of DM, CP and EE were similar for C vs. PT. However, PT diets supported higher digestibilities of TC ($P$ = 0.05), NFC ($P$ = 0.003), NDF ($P$ = 0.002), ADF ($P$ = 0.04), lignin ($P$ < 0.0001), HC ($P$ = 0.006) and cellulose ($P$ = 0.01) than the control concentrate diet. Digestibility of OM tended towards significance ($P$ = 0.074) with higher values for the PT diets compared with the control diet.

While DCP linearly decreased ($P$ = 0.029) with increasing concentrate replacement, digestible organic matter fermented in the rumen (DOMR) and intake of digestible organic matter (DOM) ($P$ = 0.034), and digestible energy (DE) and metabolisable (ME) had a positive linear increase ($P$ = 0.031) (Table 4). Though digestible crude protein (DCP) intake was not affected by treatments, DOM and DE ($P$ = 0.092) and ME ($P$ = 0.089) showed a tendency for quadratic trend. Whereas DCP was higher ($P$ = 0.043) for C vs. PT, DOMR and DOM intake ($P$ = 0.022) and DE and ME intakes ($P$ = 0.018) were greater for PT diets than the control diet. However, DOM, DCP intake and energy concentration were similar for C vs. PT.

**Table 4: Nutritive indices of concentrate partially replaced with Piliostigma forage in goats**

| Item | Concentrate replacement level | | | SEM | *P*-value | | |
|---|---|---|---|---|---|---|---|
| | 0% | 25% | 50% | | Linear | Quadratic | C vs. PT |
| DCP (%) | 11.72 | 10.77 | 10.01 | 0.60 | 0.029 | 0.866 | 0.043 |
| DOM (%) | 61.71 | 65.19 | 62.91 | 1.66 | 0.498 | 0.092 | 0.155 |
| Intake (g/d) | | | | | | | |
| DCP | 42.80 | 44.60 | 43.14 | 3.98 | 0.934 | 0.645 | 0.762 |
| DOM | 224.91 | 269.79 | 272.12 | 17.30 | 0.034 | 0.205 | 0.022 |
| DOMR | 146.19 | 175.36 | 176.88 | 11.24 | 0.034 | 0.204 | 0.022 |
| DE (MJ/d) | 4.27 | 5.14 | 5.14 | 0.31 | 0.031 | 0.160 | 0.018 |
| ME (MJ/d) | 3.60 | 4.33 | 4.33 | 0.26 | 0.031 | 0.160 | 0.018 |
| Energy level | | | | | | | |
| DE (MJ/kg) | 11.73 | 12.39 | 11.95 | 0.32 | 0.499 | 0.092 | 0.155 |
| ME (MJ/kg) | 9.87 | 10.43 | 10.06 | 0.260 | 0.50 | 0.089 | 0.153 |

DCPI: digestible crude protein intake; DOMI: digestible organic matter; DOMR: digestible organic matter fermented in the rumen; DE: digestible energy; ME: metabolizable energy; C vs. PT: control diet versus Piliostigma diets.
DE = 0.19 x Digestible organic matter (DOM) in % DM.
Metabolizable energy = 0.16 DOM (McDonald *et al.*, 2002).

Urinary N ($P$ = 0.06) and total N excretion (TNE) ($P$ = 0.08) tended towards linear and quadratic responses respectively (Table 5). N retention (% of N intake) was quadratically ($P$ = 0.031) affected. N intake, faecal N and absorbed N were not affected by treatments. Urinary N was lower ($P$ = 0.018) for PT diets compared to control diet but N retention (% of N intake) was higher ($P$ = 0.05) for PT than for the control. N intake and absorbed, faecal N, TNE and N retention (g/d) were similar for C vs. PT.

**Table 5: Nitrogen utilization in the goats fed concentrate replaced with Piliostigma foliage**

| Item (g/d) | Concentrate replacement level | | | SEM | *P*-value | | |
|---|---|---|---|---|---|---|---|
| | 0% | 25% | 50% | | Linear | Quadratic | C vs. PT |
| N intake | 9.96 | 10.46 | 10.73 | 0.89 | 0.417 | 0.884 | 0.438 |
| Faecal N | 3.09 | 3.16 | 3.80 | 0.50 | 0.201 | 0.530 | 0.397 |
| Urinary N | 1.42 | 0.85 | 0.91 | 0.70 | 0.06 | 0.144 | 0.03 |
| TNE | 4.52 | 4.01 | 4.72 | 0.33 | 0.57 | 0.08 | 0.614 |
| N absorbed | 6.86 | 7.30 | 6.93 | 1.10 | 0.956 | 0.689 | 0.803 |
| N retention | | | | | | | |
| g/d | 5.44 | 6.45 | 6.01 | 0.89 | 0.579 | 0.426 | 0.386 |
| % of N intake | 51.10 | 61.64 | 55.43 | 3.63 | 0.278 | 0.037 | 0.05 |

TNE: total nitrogen excretion; C vs. PT: control diet versus Piliostigma diets.

Linear trends were observed for ruminal pH ($P$ = 0.001), and VFA and estimated microbial protein synthesis (MPS) ($P$ = 0.034), but there were no treatment effects on ruminal $NH_3$-N and total N (Table 6). While ruminal pH ($P$ = 0.001), VFA ($P$ = 0.025) and MPS ($P$ = 0.022) were lower for C vs. PT, $NH_3$-N and total N were similar for C vs. PT.

**Table 6: Effect of partial replacement of concentrate on rumen fermentation pattern and microbial protein synthesis in goats**

| Parameter | Concentrate replacement level | | | SEM | *P*-value | | |
|---|---|---|---|---|---|---|---|
| | 0% | 25% | 50% | | Linear | Quadratic | C vs. PT |
| pH | 6.26 | 6.63 | 6.80 | 0.09 | 0.001 | 0.243 | 0.001 |
| $NH_3$-N (mg/L) | 188.10 | 176.90 | 173.86 | 8.66 | 0.152 | 0.606 | 0.141 |
| VFA (mmol/L) | 121.54 | 127.10 | 130.34 | 2.02 | 0.034 | 0.844 | 0.025 |
| Total N (mg/L) | 1983.18 | 2101.67 | 1910.6 | 96.53 | 0.481 | 0.114 | 0.793 |
| MNY (g/d) | 4.68 | 5.61 | 5.66 | 0.28 | 0.034 | 0.208 | 0.022 |
| MPS (g/d) | 29.24 | 35.07 | 35.37 | 2.25 | 0.034 | 0.208 | 0.022 |

MNY: microbial N yield; MPS: microbial protein synthesis; C vs. PT: control diet versus Piliostigma diets.

**DISCUSSION**

Chemical constituent of PT foliage is within the range of values previously documented (Tona, 2011; Ighodaro *et al*., 2012), though the NDF was lower. The CTs level is much lower than the threshold level at which tannins impair nutrient utilization and performance in ruminants. Considering its relatively high CP and lower fibre fractions, PT may be considered as a good source of supplementary fodder of high nutritive value for ruminants. The lower CP content of TST was expected because it is a typical roughage diet with more fibre. The supplementary concentrate met the requirements for growing ruminants.

Linear decrease in concentrate intake with increasing replacement of concentrate with PT foliage is obviously due to reduced availability of the concentrate. Feed intake is a function of availability *ceteris paribus.* The same holds true for higher consumption of PT foliage by goats fed 50% concentrate replacement relative to 25% replacement. The results agree with previous studies (Das and Ghosh, 2007; Kholif *et al*., 2015). Increased intakes of feed and most nutrients with partial replacement of concentrate with PT foliage suggests that diets containing PT foliage may be more palatable than the control diet. Piliostigma tree leaves have been reported to be palatable and nutritious (Tona, 2009; Ighodaro *et al*., 2012) and was well consumed by the animals in the current study. The PT foliage stimulated more intake of the basal diet relative to the control diet, in concurrence with earlier reports (Das *et al*., 2011). Olafadehan *et al*. (2014b) attributed lower intake of diet containing up to 60% dried rumen content to reduced palatability and acceptability. Kholif *et al*. (2015) similarly attributed increased intakes of feed and most nutrients by goats, fed *Moringa oleifera* leaf meal (MLM) as replacement to sesame meal, to enhanced palatability. The increased DM intake also suggests low ruminal degradability of PT foliage since low ruminal degradability of diet has been reported to increase feed intake due to increased provision of undegradable protein (M'hamed *et al*., 2001, Kholif *et al*., 2014, 2015). The reduced feed intake by goats fed the control diet may be due to the fact that the diet was largely concentrate which could have provided more degradable carbohydrate (NFC) that resulted in substantial decrease in ruminal pH and fibre digestion and consequently the decreased feed intake.

Lack of treatment effect on OM digestibility contradicted earlier observations of concentrate replacement with tree leaves (Richards *et al*., 1994; Das and Ghosh 2007; Das *et al*., 2011). The differences in results can be due to factors such as structure of the leaves, soft vs. hard, smooth vs. waxy or hairy, morphology of the plant as well as anti-nutritional components, particularly CTs. The decreased *in vivo* fibre digestibility observed in the control diet (Table 3) can be attributed to lower pH values (Table 5) found in the rumen of these goats compared with those fed concentrate replacement with PT foliage. Low ruminal pH generally inhibits the activities of rumen celluloytic bacteria. However, the possibility of latent acidosis in goats fed high concentrate control diet is ruled out because the pH was above the cellulolytic threshold of 6.2 (Mould and Orskov, 1983) in the current study. Replacement of concentrates with jack fruit leaves and Barhar leaves in previous studies produced similar responses (Das and Ghosh, 2007; Das *et al*., 2011). Similarly, Sultana *et al*. (2015) partially and completely replaced the concentrate feed mixture from the diets of Black Bengal goats with Moringa leaves and found that partial replacement increased nutrients intake and NDF digestibility compared to the complete replacement and control.

Though CP digestibility was not affected by diets, linear decrease in DCP with increasing concentrate replacement could be explained by high CP content of the concentrate relative to the PT foliage. The same holds true for higher DCP of the control diet than the PT diet. Linear increase in intakes of DOM, DE and ME, and DOMR with consequential greater values of these parameters in PT diet relative to control diet could be due to the higher feed intake of goats fed the PT foliage as a replacement for the concentrate. All things being equal, intake of nutrients is generally a function of DM intake (Olafadehan *et al*., 2014b). Similarly, the results can also be attributed to OM digestibility which tended to be higher in PT since DOM, DOMR, DE and ME are derivatives of OM digestibility. Though energy levels of the diets were not significantly affected, they tended to be higher for PT diets compared with the control diet. The results suggests a high nutritive value for PT foliage.

Lower urinary N output of the PT diet suggests the beneficial level of its CTs. Tannins at low level bind the dietary protein thus preventing its excessive degradation by ruminal microbes (Olafadehan, 2011,). Higher urinary N excretion of the control diet is suggestive of its faster degradation. The beneficial effect of CTs of PT foliage is further confirmed by its higher N retention (% of N intake) and the TNE which tended to be lower. Olafadehan (2013) attributed improved N absorption and retention in goats fed tannin-containing *Pterocarpus erinaceus* (PE) forage relative to tannin-free grass diet to the beneficial effects of the CTs of the PE forage. Again, lower N retention of the control diet and its TNE which tended to be higher suggest faster rate and extent of degradation of N of the concentrate. The results contradict earlier reports of Das *et al*. (2011) and Richards *et al*. (1994). Variations in results could be due to differences in quality of the forage used as a replacement for concentrate. Reduced CP digestibility and N utilization when tree fodders replaced concentrate has been attributed to slower rate and extent of degradation of N from the leaves which is bound to the fibre fraction.

Linear progressive increase in ruminal pH as forage level in the diet increased and lower pH of concentrate vs. concentrate replacement with forage is consistent with previous findings (Kholif *et al*., 2015). Increased rumination and salivation when ruminants eat high forage diet generally raise the ruminal pH. As earlier conjectured, goats did not develop acidosis with any of the diets used in this study. According to Nocek (1997), when ruminal pH is maintained above 5.5, a balance and equilibrium exists between lactate producers and utilizers, such that lactic acid does not accumulate in the rumen. The ruminal $NH_3$-N in the present study was above the recommended minimum level of 50-60 mg/L reported to maximize rumen microbial synthesis (Salter and Slyter, 1974). Lack of treatment effect on ruminal $NH_3$-N, which contradicted earlier findings (Richards *et al*., 1994; Das *et al*., 2011, Kholif *et* al., 2015), can be ascribed to similar N intake and possibly low CP degradability of the PT foliage. The results confirmed the speculation that CTs of PT foliage were beneficial and produced mild or low protein binding effect. The increased VFA concentrations with increasing concentrate replacement and higher VFA of PT diet than that of control diet can be explained by higher intakes of DM and DOM by goats fed the PT diets. Production of VFA has shown to be influenced by feed and DOM intakes (Das *et al*., 2011; Ramos *et al*., 2009). The results are at variance with those of Soliva *et al*. (2005); Das and Ghosh (2007) and Das *et al*. (2011) but agree with those of Ramos *et al*. (2009) and Kholif *et al*. (2015). Feeding the control concentrate diet may have diminished total viable rumen bacterial numbers and activities relative to the PT diet because rumen MPS was decreased by the concentrate, which may be due, at least in part, to reduced fibre digestion and a depressed capacity of rumen bacteria to digest feed. It appears that the lower ruminal pH of the control diet reduced the activities of the rumen bacterial as earlier speculated. Also, higher cellulose concentration of PT diets relative to the concentrate may be responsible for greater VFA of the PT diets. According to Okunade *et al*. (2014b), cellulose is the main source of volatile fatty acids used as energy source in ruminants

## CONCLUSION

The study underscores the nutritive value of *P. thonningii* foliage as a replacement for concentrate in diets of goats. The replacement of concentrate with Piliostigma forage enhances feed intake, fibre digestibility, microbial protein synthesis, ruminal fermentation and N retention. A 50% concentrate replacement with *P. thonningii* leaves can be advocated for goats under the current experimental conditions.

## CONFLICTS OF INTEREST

The authors declare that there are no present or potential conflicts of interest between them and other people or organizations that could inappropriately bias the work.

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