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ORIGINAL ARTICLE

# Performance and hemtochemical parameters of buck-kids fed concentrate partially replaced with tropical *Piliostigma thonningii* foliage

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## ABSTRACT

Fifteen 5-month-old Red Sokoto buck-kids, (6.6 ± 0.71 kg body weight (BW)) randomly distributed into three groups of five animals per group, were used to study the effects of supplementary concentrate partially replaced with *Piliostigma thonningii* (PT) foliage on the growth performance, economic benefit and blood profile in a completely randomized design using analysis of variance. The goats in group 1 received 100% supplementary concentrates (PT0), groups 2 and 3 received 25% (PT25) and 50% (PT50), respectively, of concentrate replaced with an equal amount (dry matter basis) of *Piliostigma* foliage. The goats were fed a basal diet of threshed sorghum top (TST). Intake of concentrate, hemoglobin, mean corpuscular hemoglobin concentration, mean corpuscular hemoglobin, total feeding cost and cost/kg BW were greater ($P < 0.05$) for PT0 than for PT25 and PT50. Consumption of *P. thonningii* foliage was greater ($P < 0.05$) for PT50 relative to PT25. Tannin consumption of the treatment diets were greater ($P < 0.05$) than that of the control concentrate diet. Serum urea N reduced ($P < 0.05$) with increasing level of concentrate replacement, while serum glucose was higher ($P < 0.05$) in PT0 than in PT50. However, means of all blood measurements were within normal ranges for goats. Net benefit showed this rank order: PT0 < PT50 < PT25 (all $P < 0.05$). Both differential and relative benefits were higher ($P < 0.05$) for PT25 than for PT50. *P. thonningii* foliage can replace 50% of supplemental concentrate without impairing feed intake, growth performance and health of buck-kids.

**Key words:** *blood, goat, Piliostigma thonningii, tannins.*

## INTRODUCTION

Goats play a vital role in the livelihoods of smallholder farmers in developing countries. Smallholder goat farmers depend predominantly on roughages, particularly pasture for feeding their animals. Thus, dry season feeding has always been a constant problem, as feed supplies are limited both in quantity and quality which result in reduced performance and productivity (Olafadehan & Adewumi 2009). It is, therefore, generally desirable to increase intake and digestion and therefore performance of goats through supplementation (Vazzana *et al.* 2014; Gobindram *et al.* 2017). The incorporation of concentrates into ruminant diets is intended to increase dietary energy and nutrients, and to optimize the efficiency of feed utilization (Olafadehan *et al.* 2016). Supplementation with concentrate is reported to increase production performance (Das & Ghosh 2001). However, considering the soaring cost and availability of concentrate, it will be wise to use it judiciously and replace it with locally available feed ingredients like tree fodders. Tree fodders are important in providing nutrients to grazing ruminants in tropical environments where inadequate feeds are a major constraint.

*Piliostigma thonningii* (PT) is a leguminous plant found mostly in woodland habitats (Lock &

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Simpson 1999). The leaves are browsed by ruminants during the dry season. However, like other leguminous browse fodders, it contains thousands of compounds such as condensed tannins (CT) which, depending on their nature and concentration, can have beneficial or deleterious effects on animals (Jurgens 1997). The secondary metabolites, particularly CT, in tree fodders could produce intoxication if consumed in excess (Olafadehan *et al.* 2014a). The effect of feeding animals on some tree leaves containing high levels of anti-nutritional compounds can be detrimental to the health of animals (Olafadehan 2011a). One of the fastest ways of ascertaining the toxicity or otherwise of ingested leguminous browse fodders is through the examination of the blood of the animals consuming them (Olafadehan 2011a).

The aim of this study is to investigate the effect of partial replacement of supplemental concentrate with tannin-containing PT foliage on the performance, economic benefit and blood profile of Red Sokoto goats.

## MATERIALS AND METHODS

### Location of the study

The experiment was carried out at the sheep and goat unit of the University of Abuja Teaching and Research Farm, Abuja, Nigeria. The study site lies between latitude 8° 55′N and 9° 00′E and longitude 7° 00′N and 7° 05′E. The mean annual rainfall and temperature range from 1100 to 1650 mm and 25.8 to 35.1°C, respectively. Relative humidity is about 60% during the raining season and 30% during the dry season. The dry season lasts for 6 months starting from November to April.

### Animals and treatment

Fifteen clinically healthy Red Sokoto buckling kids sourced from different herds, about 5 months old with $6.60 \pm 0.71$ kg mean initial body weight (BW), were randomly assigned to one of three treatments in a completely randomized design for a period of 70 days. The dietary treatments were: (i) supplementary concentrate fed at 5% BW; (ii) 25% of concentrate replaced with an equal amount (DM basis) of *P. thonningii* foliage; and (iii) 50% of concentrate replaced with an equal amount (DM basis) of *P. thonningii* foliage. The concentrate ration was formulated to contain (g/kg) 250 maize, 270 corn bran, 300 dried brewers' grains, 120 groundnut cake, 10 urea, 20 limestone, 20 salt and 10 vitamin-mineral premix. The basal diet, threshed sorghum top (TST), and water were offered *ad libitum*, while the diets were offered twice daily (08.00 and 15.00 hours) in two equal portions.

All goats were treated with oxytetracycline and ivomectin at 1 mL/10 kg and 1 mL/50 kg, respectively, prior to the onset of the experiment. Each goat was fed and kept individually in a ventilated slatted floor cage under an open-sided pen. The amount of feed offered was measured daily and representative samples were taken on a weekly basis and pooled together after the experiment. Subsamples were later taken for analysis. Goats were individually weighed at the beginning of the experiment and subsequently at 7-day intervals in the morning before feeding. The goats were kept, maintained and treated in adherence to accepted standards for the humane treatment of animals.

### Blood sample collection

On the last day of the experiment, two sets of blood samples were collected from each goat via the jugular vein puncture using hypodermic syringes into Vacutainer tubes (Becton Dickinson, Franklin Lakes, NJ, USA). Blood sampling from each animal was performed at the same hour of the day by veterinarians to minimize stress. One set of the blood samples (5 mL) was collected into plastic tubes containing ethylenediaminetetraacetic acid (EDTA) for the determination of hematological parameters. The other set of blood samples (5 mL) was collected into EDTA-free plastic tubes, allowed to coagulate at room temperature and centrifuged for 5 min at $3000 \times g$. The supernatant sera were then decanted and deep-frozen for biochemical analysis. Blood samples containing EDTA were shipped in an ice-packed cooler to the laboratory and analyzed within 6 h of collection.

### Chemical analysis

Samples of TST, *P. thonningii* foliage and concentrate supplement were dried individually in an air-draft oven at 60°C for 96 h, ground separately to pass through a 1 mm sieve in a Wiley mill and sampled for chemical analysis using the standard methods of the Association of Official Analytical Chemists (AOAC) (1995). Dry matter was determined by drying at 100°C for 24 h. Ash concentration was determined after ignition at 550°C for 4 h in a muffle furnace and used to calculate organic matter (OM). Fiber fraction analysis was by the methods of Van Soest *et al.* (1991). Hemicellulose and cellulose were estimated as differences between neutral detergent fiber (NDF) and acid detergent fiber (ADF) and ADF and lignin, respectively. CT were determined by the methods of Makkar (2003). Packed cell volume (PCV) and hemoglobin (Hb) concentrations were determined as described by Dacie and Lewis (2001). Red blood cell (RBC) and total white blood cell

 

(WBC) counts as well as the differential WBC counts were determined using the improved Neubauer hemocytometer counting chamber (BS748:1982; British Standard Institution, London, UK) after appropriate dilution. Mean corpuscular hemoglobin concentration (MCHC), mean corpuscular hemoglobin (MCH) and mean corpuscular volume (MCV) were calculated from RBC, Hb and PCV values using appropriate formulae by Dacie and Lewis (2001). Serum total protein, albumin and total globulin values were obtained by the buiret method (Reinhold 1953), and serum urea and creatinine by modified methods of Varley *et al.* (1980). Glucose and serum enzymes, alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP), were determined using a commercial test kit (Randox Laboratories Ltd., Crumlin, Co. Antrim, UK) and finally measured using a UV Spectrophotometer (SEAC, Florence, Italy).

## Economic analysis

The variable cost of feeding the goats was considered as the cost of the feeds, as all other costs (i.e. labor, capital investment, housing) were the same for all the treatments. The cost of harvesting and drying the *P. thonningii* leaves was included as part of the feed cost.

## Data analysis

Data were subjected to analysis of variance (ANOVA) for a complete randomized design, with a model that included the diet as treatment effects, using Statistical Package for the Social Sciences (SPSS 2009). When the ANOVA was significant, means were separated using Duncan's multiple range test at the level of $P \leq 0.05$. The statistical model is shown below:

$$Y_{ij} = \mu + C_i + e_{ij},$$

Where: $Y_{ij}$ = dependant variables; $\mu$ = population mean; $C_i$ = effect of concentrate replacement with *Piliostigma thonningii* foliage and $e_{ij}$ = random error assumed to be normally and independently distributed.

# RESULTS

## Chemical composition of the experimental and basal diets

The crude protein (CP), OM, ether extract and hemicellulose of the supplementary concentrate were higher than that of the *P. thonningii* foliage (Table 1). However, the NDF, ADF, ADL and cellulose of the foliage were higher than that of the concentrate. While both the *P. thonningii* foliage and the basal TST contained CT, the concentrate had no CT.

## Voluntary intake, weight gain and feed utilization efficiency

Intakes of TST, DM, CP and OM, final BW, BW gain and average daily gain (ADG), and feed conversion ratio (FCR) were similar ($P > 0.05$) among the diets (Table 2). Concentrate intake of PT25 and PT50 were lower ($P < 0.05$) than that of PT0. Intake of *P. thonningii* foliage was more ($P < 0.05$) for PT50 relative to PT25. Intake of CT of PT25 and PT50 was greater ($P < 0.05$) than for PT0.

## Hematological indices

Whereas Hb concentration, MCHC and MCH were higher ($P < 0.05$) for PT0 than for PT25 and PT50, other hematological parameters were similar ($P > 0.05$) among the diets (Table 3).

## Biochemical profiles

Except for urea N and glucose concentrations which were affected ($P < 0.05$) by dietary treatments, other indices of serum biochemistry showed no ($P > 0.05$) difference (Table 4). Urea N showed this rank order: PT0 > PT25 > PT50 (all $P < 0.05$). Serum glucose

**Table 1** Chemical composition (g/kg) of experimental diets

| Parameter | *P. thonningii* | Threshed sorghum top | Concentrate |
|---|---|---|---|
| Dry matter | 949 | 936 | 936 |
| Composition (g/kg DM) | | | |
| Crude protein | 158 | 72.1 | 186 |
| Organic matter | 909 | 872 | 934 |
| Ether extract | 43.7 | 64.5 | 99.9 |
| Neutral detergent fiber | 396 | 603 | 288 |
| Acid detergent fiber | 333 | 427 | 124 |
| Acid detergent lignin | 80.6 | 92.4 | 39.8 |
| Hemicellulose | 63.8 | 176 | 164 |
| Cellulose | 252 | 335 | 84.4 |
| Condensed tannins | 2.8 | 1.9 | ND |

ND, not detected.

**Table 2** Voluntary intake and body weight gain of goats fed concentrate partially replaced with *P. thonningii* (PT) foliage

| Parameter | Concentrate replacement with PT foliage (%) | | | SEM | *P*-value |
|---|---|---|---|---|---|
| | PT0 | PT25 | PT50 | | |
| TST intake (g/day) | 90.6 | 100.3 | 119.8 | 10.8 | 0.061 |
| Concentrate intake (g/day) | 314$^a$ | 81$^b$ | 164$^c$ | 7.12 | <0.0001 |
| *P. thonningii* forage intake (g/day) | - | 236$^b$ | 158$^a$ | 18.4 | 0.001 |
| Dry matter intake (g/day) | 405 | 417 | 442 | 38.6 | 0.511 |
| Dry matter intake (g/kg $W^{0.75}$) | 71.4 | 73.5 | 78.6 | 7.72 | 0.548 |
| Dry matter intake (g/kg of BW) | 4.01 | 4.13 | 4.42 | 4.92 | 0.495 |
| CP intake (g/kg $W^{0.75}$) | 11.4 | 10.5 | 11.4 | 1.04 | 0.658 |
| OM intake (g/kg $W^{0.75}$) | 65.7 | 66.9 | 71.5 | 5.07 | 0.526 |
| Tannins intake (g/kg $W^{0.75}$) | 0.03$^b$ | 0.15$^a$ | 0.12$^a$ | 0.04 | 0.001 |
| Tannins intake (g/kg of BW) | 0.02$^b$ | 0.08$^a$ | 0.07$^a$ | 0.02 | 0.001 |
| Initial weight (kg) | 6.6 | 6.5 | 6.6 | 0.71 | 0.983 |
| Final weight (kg) | 13.6 | 13.7 | 13.4 | 1.23 | 0.950 |
| Total weight gain (kg) | 7.0 | 7.2 | 6.8 | 0.70 | 0.797 |
| Average daily gain (g/day) | 100 | 103 | 97.1 | 10.03 | 0.799 |
| Feed conversion ratio | 4.05 | 4.05 | 4.55 | 0.48 | 0.487 |

Means with different superscripts in the same row are significantly different ($P < 0\ .05$). TST, threshed sorghum top; CP, crude protein; OM, organic matter.

**Table 3** Hematological indices of the goats fed concentrate partially replaced with *P. thonningii* (PT) foliage

| Item | Concentrate replacement with PT foliage (%) | | | SEM | *P* value |
|---|---|---|---|---|---|
| | PT0 | PT25 | PT50 | | |
| Packed cell volume (%) | 34.0 | 33.5 | 32.5 | 0.88 | 0.296 |
| Hemoglobin (g/L) | 113$^a$ | 97.3$^b$ | 94.7$^b$ | 2.36 | 0.001 |
| Red blood cells ($10^{12}$/L) | 14.5 | 14.4 | 14.5 | 0.53 | 0976 |
| MCHC (%) | 33.1$^a$ | 29.1$^b$ | 29.1$^b$ | 0.74 | 0.002 |
| MCH (fmol) | 7.78$^a$ | 6.75$^b$ | 6.51$^b$ | 0.24 | 0.004 |
| Mean corpuscular volume (fL) | 23.4 | 23.2 | 22.4 | 0.88 | 0.491 |
| White blood cells ($10^9$/L) | 12.3 | 10.6 | 11.1 | 1.01 | 0.302 |
| Lymphocytes (%) | 60.5 | 63.6 | 58.0 | 6.84 | 0.735 |
| Monocytes (%) | 2.50 | 2.00 | 2.50 | 0.66 | 0.700 |
| Neutrophils (%) | 46.7 | 45.4 | 47.7 | 6.73 | 0.939 |
| Basophils (%) | 0.09 | 0.09 | 0.09 | 0.03 | 1.000 |
| Eosinophils (%) | 4.00 | 3.30 | 3.70 | 1.02 | 0.813 |

Means with different superscripts in the same row are significantly different ($P < 0.05$). MCHC, mean corpuscular hemoglobin concentration; MCH, mean corpuscular hemoglobin.

level was higher ($P < 0.05$) in the control diet relative to the PT50, but it was similar ($P > 0.05$) between the control diet and PT25, and PT25 and PT50, respectively.

## Cost-benefit

The result of comparative cost advantage of concentrate replacement with PT leaves in goats' diets is shown in Table 5. Cost of feeding TST, savings on feeding cost and monetary value of weight gain were not ($P > 0.05$) affected by diets. Whereas cost of forage intake was higher ($P < 0.05$) for PT50 compared to PT25, differential benefit and relative benefit were higher ($P < 0.05$) for PT25 than for PT50. Cost of concentrate intake, total cost of feeding and cost/kg BW were greater ($P < 0.05$) for the control diet relative to the treatment diets. Net benefit was affected ($P < 0.05$) by diets; the rank order was: PT0 < PT50 < PT25.

# DISCUSSION

The DM, NDF and CP values of *P. thonningii* foliage were higher than earlier reports on the same forage species (Ighodaro *et al.* 2012). Difference in compositions may be due to variation in age, environmental and soil conditions and climatic factors. Although the NDF was slightly higher than the recommended value of 20–35% for effective ruminal degradation (Norton 1994; Bakshi & Wadhwa 2004), it was lower than 60% value at which feed intake is depressed (Meissner *et al.* 1991). The CP content of the *P. thonningii* foliage was within the range of the requirements for small ruminants gaining about 50 g BW daily (Paul *et al.* 2003). These results suggest *P. thonningii* foliage as a good browse fodder for ruminant nutrition. Although the CP of the basal TST is low, it is slightly higher than the 7% recommended dietary CP level for efficient rumen

 

**Table 4** Biochemical profiles of goats fed concentrate partially replaced with *P. thonningii* (PT) foliage

| Item | Concentrate replacement with PT foliage (%) | | | SEM | *P*-value |
|---|---|---|---|---|---|
| | PT0 | PT25 | PT50 | | |
| Urea nitrogen (mmol/L) | 3.20[a] | 2.43[b] | 1.87[c] | 0.08 | 0.003 |
| Alkaline phosphatase (UI/L) | 23.4 | 23.2 | 22.4 | 2.02 | 0.229 |
| Alanine aminotransferase (UI/L) | 12.3 | 10.6 | 11.1 | 0.73 | 0.138 |
| Aspartate aminotransferase (UI/L) | 60.5 | 63.6 | 58.0 | 7.73 | 0.846 |
| Glucose (mmol/L) | 2.90[a] | 1.83[ab] | 1.13[b] | 0.29 | 0.020 |
| Cholesterol (mmol/L) | 2.00 | 2.30 | 2.10 | 0.43 | 0.784 |
| Total protein (g/L) | 75.9 | 71.4 | 68.9 | 6.93 | 0.620 |
| Albumin (g/L) | 37.0 | 35.4 | 34.9 | 4.44 | 0.886 |
| Globulin (g/L) | 38.8 | 36.0 | 34.0 | 3.57 | 0.442 |
| Albumin : globulin ratio | 0.95 | 1.00 | 1.03 | 0.12 | 0.804 |
| Calcium (mg/dL) | 2.83 | 2.70 | 2.60 | 0.02 | 0.180 |
| Phosphorus (mg/dL) | 5.20 | 5.00 | 4.90 | 0.36 | 0.824 |
| Potassium (mEq/L) | 4.35 | 4.28 | 3.93 | 0.41 | 0.603 |
| Sodium (mEq/L) | 150 | 148 | 147 | 4.39 | 0.821 |
| Magnesium (mg/dL) | 2.04 | 2.20 | 2.11 | 0.12 | 0.891 |

Means with different superscripts in the same row are significantly different ($P < 0\ .05$).

**Table 5** Cost-benefit of concentrate partially replaced with *P. thonningii* (PT) foliage for goats

| Parameter | Concentrate replacement with PT foliage (%) | | | SEM | *P*-value |
|---|---|---|---|---|---|
| | PT0 | PT25 | PT50 | | |
| Cost of TST intake ($) | 0.57 | 0.37 | 0.38 | 0.10 | 0.075 |
| Cost of forage intake ($) | - | 1.70[b] | 2.10[a] | 0.09 | 0.004 |
| Cost of concentrate intake ($) | 12.9[a] | 7.17[b] | 6.51[b] | 1.07 | <0.0001 |
| Total cost of feeding ($) | 13.5[a] | 9.19[b] | 8.99[b] | 1.16 | 0.002 |
| Savings on cost of feeding (%) | - | 34.1 | 33.3 | 7.84 | 0.900 |
| Cost/kg BW ($) | 1.94[a] | 1.27[b] | 1.33[b] | 0.19 | 0.004 |
| Cost/kg of chevon ($) | 7.5 | 7.5 | 7.5 | | |
| Value of weight gain ($) | 52.5 | 54.0 | 51.0 | 11.3 | 0.797 |
| Net benefit ($) | 39.0[c] | 48.8[a] | 42.0[b] | 0.68 | 0.414 |
| Differential benefit ($) | - | 5.24[a] | 2.96[b] | 0.07 | 0.040 |
| Relative benefit (%) | - | 15.1[a] | 8.89[b] | 1.34 | 0.042 |

Means with different superscripts in the same row are significantly different ($P < 0\ .05$). TST, threshed sorghum top; 1$ = 160 naira (Nigeria currency) as at March 2014.

microbial activities (NRC 1981). The CT contents of both the PT and the TST were below the threshold level at which CT affects voluntary intake and feed utilization.

Greater concentrate intake of goats fed PT0 relative to goats fed PT25 and PT50 is obviously due to more accessibility of the PT0 goats to the concentrate. Similar feed intake among the treatments indicates the palatability and acceptability of the PT foliage by the goats. Nutrient intake showed a parallel trend as with DM intake, because nutrient intake has been reported to be a function of feed intake (Olafadehan *et al.* 2014b). These findings are confirmed by Das *et al.* (2011), who reported no difference in DM and OM intakes when concentrate was partially replaced with Barhar leaves in the diets of growing goats. Similar ADG and FCR of the goats show that concentrate replacement with 50% tannin-containing PT foliage did not impair the growth performance and efficiency of feed utilization. The results agree with earlier reports on replacement of concentrate with mulberry foliage (Miller *et al.* 2005) but disagree with that in which concentrate was replaced with jackfruit foliage (Das & Ghosh 2007). Variation in results could be due to such factors as quality of the basal diet, type of forage fed, level of replacement and feeding strategy. It appears that the CTs of PT foliage were beneficial as they were below the threshold level at which CTs are detrimental.

The non-significantly affected PCV and RBC of the experimental goats indicate that diets did not promote anemic conditions and depress erythropoiesis in the goats. Gbore and Akele (2010) earlier attributed reduced PCV and erythrocyte values in rabbits fed fumonisin-containing diets to an anemic situation, and reduced synthesis and concentration of erythrocytes. Although the Hb of the control diet was higher than the treatment diets, values were within the range of 80–140 g/L reported for healthy goats (Sirois 1995). Therefore, higher Hb concentration of the control diet suggests greater Fe levels of the concentrate and thus intake compared to the treatment diets. Das *et al.* (2011) also reported reduced Hb concentration when concentrate was replaced with Barhar leaves. Determination of erythrocytic indices such as MCV, MCH and MCHC is helpful in classifying certain anemias. Lower MCHC and MCH of the treatment diets may be due to the CT in the PT leaves. However, since the erythrocytic indices were within the physiological ranges for healthy goats (Sirois 1995), the depressed values might not pose any serious health problem. Lack of diet effect on WBC and its differentials, which were within the established ranges for healthy goats (Sirois 1995), is an explicit indication that the PT foliage did not induce tannic acid toxicosis and compromise the immune system of the goats.

The lower plasma urea N of goats fed PT leaves suggests reduced ruminal $NH_3$-N levels, in accordance with previous findings where jackfruit and Barhar leaves replaced concentrates (Das & Ghosh 2007; Das *et al.* 2011). The reduced serum urea N level of the PT based diets is an indication of a decreased degradability of the protein of the forage and the beneficial effect of its CT. Condensed tannins at low levels bind the dietary protein and prevent its excessive degradation by rumen microbes. The lower serum urea N of PT diets, therefore, indicates the superiority of its protein relative to the concentrate, since serum urea N is a product of protein and amino acid catabolism in the body and negatively correlates with nitrogen deposition and protein or amino acid utilization (Olafadehan 2011a; Chen *et al.* 2015). The serum urea N levels were within the normal established range (3.5–10.7 mmol/L) for goats (Sirois 1995). Similar serum enzymes (ALT, AST and ALP) values among the diets imply no damage to the liver and kidney and negative influence on the functions of organs associated with blood metabolism (Vakili *et al.* 2013). Serum enzyme activities above the normal ranges are abnormal and indicate that animals might have suffered liver and/or kidney damage (Olafadehan *et al.* 2014a). The decreased plasma glucose level of the PT diets is suggestive of increased acetate and decreased propionate production with increasing PT leaves in the diet. Due to higher fiber levels of the PT foliage than the concentrate, replacement of the concentrates with PT leaves must definitely have increased the fiber content of the PT diets. With more fiber in the PT diets, acetate production might have increased at the expense of propionate owing to low carbon flow through electron accepting channels such as the glycolytic acid-propionate production pathway (Van-Houlert 1983). The results concur with earlier studies (Das & Ghosh 2007; Das *et al.* 2011). However, the normal range of blood glucose level (1.1–3.0 mmol/L; Sirois 1995) for all treatments indicates that the depressed serum glucose levels of goats fed 50% of concentrate replacement with PT leaves was not due to hypoglycemic conditions. Similar cholesterol levels of all the animals indicate absence of hypocholesterolemia. Since glucose and cholesterol levels were within the normal ranges, possibilities of anorexia, diabetes, liver dysfunction and malabsorption of fat, which are the symptoms of abnormal glucose and cholesterol levels in the blood (Žubčič 2001) are ruled out. Lack of treatment effect on plasma protein indices, which were within the normal ranges (Fraser & Mays 1986), indicates adequate humoral immunity and protein synthesis of the animals (Abonyi *et al.* 2013). Similar serum mineral values of all the animals suggest that concentrate replacement with PT leaves did not interfere with the availability and absorption of major serum minerals, because the values were within the normal ranges for healthy goats (Sirois 1995).

A reduction of 4.27 and 4.47/kg of diet was obtained when 50 and 25% PT, respectively, replaced concentrate. With these, savings on the feeding cost were 34.14 and 33.27% for PT25 and PT50 relative to PT0. Cost of feed/kg BW showed that it was markedly cheaper and more economical to produce 1 kg of BW by replacing concentrates with PT foliage. This is in agreement with previous studies where unconventional ingredients were used to replace conventional ingredients (Olafadehan 2011b; Olafadehan *et al.* 2014b). The higher net economic benefit in the treatment diets relative to the control diet was a reflection of the lower feed cost of these diets. Differential benefits showed that goats fed PT25 and PT50 had higher benefits of 5.24 and 2.96, respectively, than the control group goats. Also replacements of concentrates with PT foliage resulted in economic benefits which were 15.1% and 8.89% higher in PT25 and PT50, respectively, than in PT0. However, higher net, differential and relative benefits of PT25 than PT50 indicate that this diet was economically superior and of better quality. The greater economic benefits of replacing concentrates with PT foliage reflected the quality of this browse fodder, as a feed for goats, and its lower price.

## Conclusion

The results obtained in this study show that supplementary concentrates can be partially replaced with low tannin-containing *P. thonningii* foliage in goats' diets up to 50% without compromising feed consumption and utilization, growth performance and health status of the animals. However, 25% replacement of concentrates with *P. thonningii* forage is more economically viable than 50% replacement.

 

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