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# Effect of Cowpea (*Vigna unguiculata*) Pasture Grazing on Growth, Gastrointestinal Parasite Infection and Immune Response Biomarkers of Goat

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**Abstract**

The objective of this study was to evaluate the effect of grazing cowpea pastures on growth, parasite egg count and biomarkers of immune response in goats. Spanish and Savannah goats ($n$ = 48) stratified by initial body weight (42.0±7.0 kg) and fecal egg count (FEC), were randomly assigned to three pasture forages (Cowpea varieties: Mississippi silver (MS), or Iron and Clay (IC) or Pearl millet (PM) as control with 4 replicates, for a 28-day feeding trial. Forage samples collected at the start of the study were analyzed for nutrients, chemical and polyphenols content. Body weight, body condition score, and fecal egg count were measured weekly. Blood was collected from goats on days 0 and 28 for PCV and white blood cell differential counts. The concentration of total proteins, prostaglandin E2 (PGE2) and total antioxidant capacity (TAC) were evaluated in blood serum. Concentration of DNA isolated from fecal samples was used as a measure of gut health. Goats grazed on cowpea forage (MS and IC) had higher body weight ($p$ = 0.01) compared to goats grazed on PM. Percent lymphocyte ($p$ = 0.008) and neutrophil ($p$ = 0.013) increased in MS fed goats. Goats grazed on MS pasture had decreased FEC ($p$ = 0.03) also. Cowpea pasture grazing had no effect on serum protein concentration, PCV and BCS ($p > 0.05$), but decreased PGE2 concentration in serum. The concentration of TAC in serum, increased at day 28 ($p < 0.05$). The concentration of fecal microbial DNA decreased in all the treatment groups at day 28. Cowpea forage grazing had an impact on body weight, FEC, and blood serum parameters (PGE2, TAC) in goats. These results demonstrate that freshly grazed cowpea forage has potential impact and benefits on growth and health of goats. Integrating cowpea diet in goat feeding system may enhance growth performance, stimulate and prime the immune system for defense against gastrointestinal parasites.

**Keywords:** antioxidant, cowpea, goats, fecal egg count, prostaglandin E2, innate immunity

## 1. Introduction

Small ruminant production is a growing industry as a result of demographic changes in populations and the global demand for goat and sheep products. Major challenges for producers with economic impact include gastrointestinal nematode (GIN) parasites especially the blood-feeder *Haemonchus contortus*, that are associated with increased mortality and poor weight gain (Molento, 2009; Hamilton et al., 2017). These challenges reduce meat, milk and fiber production and cause estimated loss of "tens of billions of dollars worldwide" (Roeber, Jex, & Gasser, 2013). The GIN parasites are typically controlled using anthelmintic drugs, furthermore, overuse of these drugs has resulted in increased resistance rendering this method ineffective in GIN control. The use of bioactive plants containing condensed tannins has been studied and suggested as a potential sustainable

alternative non-chemical strategy for GIN control in small ruminants (Van Wyk, 2001). Animal feed resources and supplements that decrease gastrointestinal parasites, and improve growth and production are therefore of great interest to producers. Condensed tannin-rich forages with efficacy against GIN include sulla (*Hedysarum coronarium*; Niezen, et al., 1995), sericea lespedeza (*Lespedeza cuneata*; Min et al., 2004), sainfoin (*Onobrychus viciifolia*; Heckendorn et al., 2006), birdsfoot trefoil (*L. corniculatus*; Heckendorn et al., 2007). Sericea lespedeza a legume with high amounts of condensed tannins, has an anthelmintic effect (Min et al., 2004) when grazed as a fresh forage (Terrill et al., 2009; Mechineni et al., 2014) and impacts immune response gene expression (Worku et al., 2016; Asiamah et al., 2016).

Cowpea (*Vigna unguiculata* L. Walp), is a heat and drought-tolerant annual legume adapted to a wide range of soil and climate conditions (Singh et al., 2010). It is cultivated for its seeds and fodder, used as food for humans and feed for animals respectively (Singh et al., 2003). In livestock production, cowpea is fed as fresh forage, hay, stovers, or haulums. Cowpea is highly nutritious, contains good quality proteins and carbohydrates (Sreerama et al., 2012), and has been suggested as a protein supplement for improved nutrition of ruminants (Etana et al., 2013). Additionally, cowpea forage contains phenolic compounds including flavonoids, tannins (Cai et al., 2003) and these bioactive compounds have antioxidant properties that help to combat oxidative stresses and diseases (Adjei-Fremah, 2017). *In vitro* studies by Adjei-Fremah et al. (2015) have shown that cowpea polyphenol extracts impact antioxidant status in bovine blood and regulate gene expression (Adjei-Fremah et al., 2016a, 2016b, 2016c, 2016d). Cowpea plants are grazed by cattle (Pitman et al., 2015), and sheep and goats (Mubi, Midau & Hamdalla, 2015; Adjei-Fremah, 2016c) as a summer legume. More recently, cowpea used as a summer finishing diet in cattle resulted in improved meat quality and marbling score, and higher consumer steak preference (Schmidt et al., 2013). It is important to understand goat growth and health performance when allowed to graze fresh cowpea pasture. The objective of this study was to evaluate the effect of cowpea forage on growth, parasite egg count and biomarkers of immune response in goats.

## 2. Method

### *2.1 Ethical Statement*

The experimental procedure and protocols used were approved by the North Carolina A&T State University Institutional Animal Care and Use Committee.

### *2.2 Establishment of Feeding Paddocks*

The experiment was conducted at the Upper Piedmont Station, Reidsville, NC. Twelve pasture grazing plots (0.15 ha/each) were established consisting of three main forage groups; 1) Pearl millet (PM; *Pennisetum americanum*), two varieties of cowpea commonly used as fodder in Southeastern US; 2) Mississippi Silver cowpea (MS), and 3) Iron and Clay cowpea (IC) with 4 replicated paddocks for each forage type. Soil testing on pasture plots was done by the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) Agronomic division. Commercially purchased seeds of two cowpea varieties (MS and IC) and pearl millet were planted in the plots. The goats were allowed to graze the plots 40 d after planting. There was adequate forage material in each paddock throughout the 28 d study period.

### *2.3 Chemical Composition of Feed and Extract Preparation*

Forage samples from PM, MS and ID were randomly collected from each paddock, bulked together and sent for chemical analysis at the NCDA&CS, Food, and Drug Protection Division Laboratory, Raleigh, NC. All chemical analysis were done using Association of Official Analytical Chemists (AOAC) protocols (AOAC, 2000). Leaf samples of PM, MS, and IC were randomly collected from each plot and bulked individually for analysis. Forages were analyzed on dry matter basis for crude protein (CP), unavailable protein (UP), acid detergent fiber (ADF), ash, and mineral elements. Separate forage samples were collected, freeze-dried and used for analyzing total phenolic content and condensed tannin content. Total phenolic content (TPC) was analyzed using the Folin-ciocaulteu method (Singleton et al., 1999) and condensed tannin content (CT) with the vanillin-HCL method (Price et al., 1978). Gallic acid and catechin with known concentrations were used as standards for TPC and CT, respectively. The procedure for extraction and quantification and of TPC and CT was as previously described by Adjei-Fremah et al. (2015). Extracts were prepared from PM, MS, and IC using 80% methanol(w/w).

### *2.4 Animals*

Forty-eight post-weaned goats were selected from the goat herd at the Upper Piedmont Research Station, Reidsville, North Carolina, USA. Two goat breeds Spanish ($n$ = 24) and Savannah ($n$ = 24) stratified by initial body weight (BW) (42.0±7.0 kg) and fecal egg counts (FEC), were randomly assigned to 1 of 12 grazing plots (4

goats per plot) consisting of one of the three experimental forages MS, IC forage and PM (Control). The animals were provided with water *ad libitum* throughout the study period. Phenotypic parameters such as body weight, body condition score, and FAMACHA score were measured weekly for 4 wks. Body weight was measured using a standard scale. Body condition score was scored on a scale of 1 to 5. FAMACHA was also scored on a scale of 1 to 5 using the FAMACHA eye chart (Kaplan et al., 2004) as previously described by Ekwemalor et al. (2016).

### *2.5 Blood Collection and Analysis*

Blood was collected from each animal from the jugular vein on 0 d and 28 d in EDTA Vacutainer tubes (Becton, Dickinson and Co., Franklin Lakes, NJ) and immediately stored on ice. Blood was analyzed for total cell count (TC), viable cell counts (VC), packed cell volume (PCV), white blood cells differential counts (WBC). Total cells and viable cells were determined using TC20 automatic cell counter (Bio-rad). Packed cell volume (PCV), an indicator of anemia was evaluated using an aliquot of blood in microcapillary tubes, centrifuged and measured on ahematocrit (Diamon/EC division). White blood cell differential counts using Wright staining method and 100 counts read on alight microscope following the procedure as described by Asiamah et al. (2016). Blood collected into BD vacutainer SST Gel and clot activator serum tubes was used to process serum. The tubes were centrifuged at 4500 rpm, at 4 °C for 30 mins to obtain serum. Serum was stored at -80 °C until used for analysis.

### *2.6 Fecal Sampling and Analysis*

Fecal samples were collected weekly and analyzed for parasite egg count using the modified McMaster's method. Fecal egg counts were measured in duplicate and the mean was multiplied by 50 (Kaplan et al., 2004). Data for fecal egg counts were log transformed before statistical analysis. Fecal microbial DNA was isolated using the QIAamp stool DNA kit (Qiagen) following the manufacturer's protocol.The concentration and purity of total fecal DNA were measured using a NanoDrop ND-1000 spectrophotometer (Thermo Scientific, DE, USA)

### *2.7 Blood Serum Assays*

Serum was analyzed for total protein, prostaglandin E2 (PGE2) and total antioxidant concentrations(TAC). Total serum protein concentration was measured using the Pierce BCA assay kit (Thermo-Scientific, Waltham, MA) following manufacturer's protocol as previously described by Obanla et al. (2016). Bovine serum albumin with known concentrations was used as astandard to quantify the level of proteins in serum samples. The secretion of Prostanglin E2 (PGE2) in serum was measured using a commercial enzyme-linked immunosorbent assay (ELISA; Cayman Chemical, An Arbour, MI) following manufacturer's protocol.

The endogenous total antioxidant capacity in blood serum (*i.e.* for 0day and 28-day samples) was determined using the OxiSelect$^{TM}$ TAC assay kit following the manufacturer's protocol (Cell Biolabs Inc., San Diego, CA) as previously described by Adjei-Fremah et al. (2015). The Cell Biolabs' OxiSelect$^{TM}$ TAC assay measures the total antioxidant capacity of biomolecules from samples through a single electron transfer mechanism. The TAC assay is based on the reduction of copper (II) to copper (I) by antioxidants such as uric acid. Serum samples were analyzed separately with the assay buffer containing copper ion reagent and incubated for 5 min and absorbance was read at 490 nm on a microplate reader (Epoch, BioTek). A standard curve ($r^2$ = 0.99) using known concentrations of uric acid was used determine the serum total antioxidant capacity.

### *2.8 Statistical Analysis*

Statistical analysis was performed using the general linear (PROC MIXED) repeated measure model in SAS (version 9, SAS Institute Inc., Cary, NC) to test for significant difference between means using the model below: $Y_{ijk} = \mu + T_i + W_j + TW_{ij} + e_{ijkl}$; $Y_{ijk}$ = dependent variable, is the observed measurement; $\mu$ = the overall population mean; $T_i$ = is the fixed effect of the treatment $i$, $W_j$ is the random effect of time $j$, $TW_{ij}$ is the interaction of treatment $i$ and time $j$, $e_{ijkl}$ = random residual effect (error) assumed normally distributed with a mean zero and variance $\sigma^2$e. Body weight, BCS, and FAMACHA score data were analyzed using PROC GLM repeated measure in SAS. Two-way ANOVA was performed on all other data, and a p-value < 0.05 was considered significant. Pearson's correlation analysis was used to determine the relationship between all the parameters measured.

## 3. Results

### *3.1 Chemical Composition of Forage Samples*

Table 1 shows chemical composition in the different forage types grazed. The crude protein content was relatively the same in all the forages. Forages from MS and IC varieties had higher TPC, 298.05 mg/GAE and 271.34 mg/GAE respectively than PM (54.92 mg/GAE). The condensed tannin content in MS and IC were 0.52 mg/CE and 0.48 mg/CE separately. There was no CT found in pearl millet forage.

Table 1. Nutrient and chemical composition in forage samples; Pearl Millet (PM), Mississippi Silver (MS), and Iron and Clay (IC) cowpea

| Chemical composition[2] | PM | MS | IC[1] |
|---|---|---|---|
| Dry matter,DM (%) | 17.38 | 20.52 | 19.26 |
| CP (% of DM) | 23.89 | 21.09 | 24.07 |
| UP(% of DM) | 1.21 | 1.47 | 0.83 |
| Adjusted crude proetin (% of DM) | 23.89 | 21.09 | 24.07 |
| ADF (% of DM) | 28.18 | 15.84 | 15.55 |
| Nitrate ion (% of DM) | 0.78 | 0.18 | 0.21 |
| Ash (% of DM) | 10.75 | 14.76 | 15.35 |
| Calcium (% of DM) | 0.65 | 1.88 | 2.48 |
| Phosphorus (% of DM) | 0.53 | 0.35 | 0.34 |
| Sulfur (% of DM) | 0.28 | 0.24 | 0.30 |
| Magnessium (% of DM) | 0.42 | 0.43 | 0.57 |
| Sodium (% of DM) | 0.01 | 0.00 | 0.00 |
| Potassium (% of DM) | 3.08 | 2.42 | 2.06 |
| Copper (ppm) | 14.00 | 8.00 | 11.00 |
| Iron (ppm) | 225.00 | 518.00 | 460.00 |
| Zinc (ppm) | 90.00 | 24.00 | 30.00 |
| Manganese (ppm) | 98.00 | 76.00 | 65.00 |
| Alumnium (ppm) | 0.24 | 1.12 | 1.10 |
| Boron (ppm) | 0.10 | 0.06 | 0.05 |
| Total phenolic content (mg/GAE) | 54.92 | 298.05 | 271.34 |
| Condensed tannin(mg/CAE) | ND[3] | 0.52 | 0.48 |

*Note*. [1] Goats grazed on these pastures for 28 d;

[2] Chemical constituents in feed were analyzed on dry matter basis (DM) using AOAC standards by North Carolina department of Agriculture and Consumer services, Food and Drug Protection Division Laboratory, Raleigh,NC, and the Food analytical Laboratory, North Carolina A&T State University;

[3] ND-Not detected.

### *3.2 Effect of Forage Type on Body Weight*

The changes in body weight over the 28 d study period is shown in Figure 1. Body weight was affected by feedtype grazed ($p$ = 0.0023). The initial body weight of MS and IC fed goats were slightly lower compared to PM animals. After 7 d, BW slightly increased in PM grazed goats. At 14 d, BW increased in MS-grazed goats and continued to day 28. Body condition score was similar between Savannah and Spanish goats. The interaction effect between BW, goat breed and feedtype was also significant ($p$ = 0.0124). The BW increased in MS-grazed Savanna goats (50.01 kg) compared to MS-grazed Spanish goats (45.83 kg).

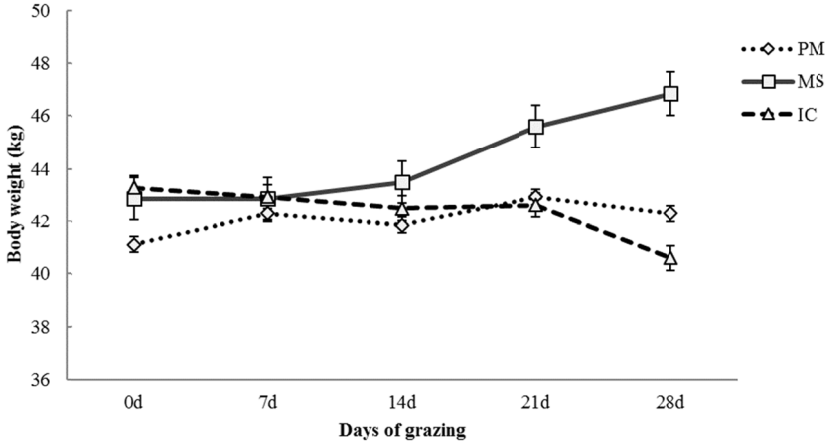


Figure 1. Body weight in goats fed pearl millet (PM), Mississippi silver (MS), and Iron and Clay (IC) cowpea

### *3.3 Effect of Forage Type on PCV, FAMACHA, BCS and WBC*

The BCS, FAMACHA, and PCV (Table 2) were not affected by forage type grazed. The packed cell volume (PCV) for all animals initially (0 d) was 32% and remained unchanged throughout the study period. Cowpea had effect on white blood cells differential count especially % lymphocytes ($p = 0.0267$) and % neutrophils counts ($p = 0.0129$). The interaction between goat breed, feedtype and % lymphocytes was also significant at $p = 0.00264$. Lymphocyte counts were highest in PM-grazed Spanish goats (75%) and lowest in MS-grazed savanna goats (43%). Feed had no effect on % monocytes,% basophil, and % eosinophil counts. Similarly, the interaction effect between goat breed, forage type and % neutrophils counts was also significant at $p = 0.0094$. Percent neutrophils increased in MS-grazed savanna goats (55%) than MS-grazed Spanish goats (28%), IC-grazed Savanna (26%) and PM-grazed Spanish goats (25%).

Table 2. Effect of cowpea pasture on hematological parameters in goats

| Parameter | PM | MS | IC | p-value |
|---|---|---|---|---|
| PCV, % | 32.0 | 32.7 | 33.1 | ns |
| FAMACHA | 3.03 | 2.29 | 2.95 | ns |
| BCS | 3.13 | 3.38 | 2.94 | ns |
| White Blood cells (%) | | | | |
| *Lymphocytes* | 73 | 57 | 64 | 0.0297 |
| *Monocytes* | 1 | 1 | 1 | ns |
| *Neutrophils* | 26 | 42 | 34 | 0.0129 |
| *Basophils* | 0 | 0 | 0 | ns |
| *Eosinophils* | 0 | 0 | 1 | ns |

### *3.4 Effect of Cowpea on Fecal Egg Count*

The effect of forage type on FEC in goats is shown in Figure 2. Fecal egg counts were slightly variable between the three forage groups at day 0. The forage type grazed had aneffect on FEC ($p = 0.026$) in goats. Although the interaction between FEC and goats breeds was non-significant ($p = 0.2406$), FEC was lower in Spanish compared to Savanah goats. Seven days after initiation of the study, goats grazed on MS cowpea forage had lower FEC compared to IC and PM pasture-grazed animals, and MS effect in reducing FEC was continuous through 21 d and 28 d relative to goats grazed on the other feed pastures.

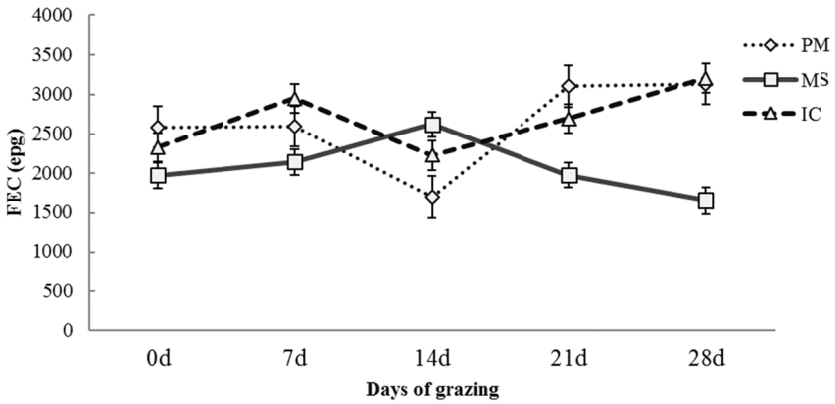


Figure 2. Effect of cowpea pasture grazing on fecal egg count in goats fed pearl millet (PM), Mississippi silver (MS), and Iron and Clay (IC) cowpea

### *3.5 Effect of Cowpea Forage on Fecal DNA Concentration*

Fecal DNA concentration is presented in Figure 3. The concentration of fecal microbial DNA decreased in all the treatment groups at day 28.

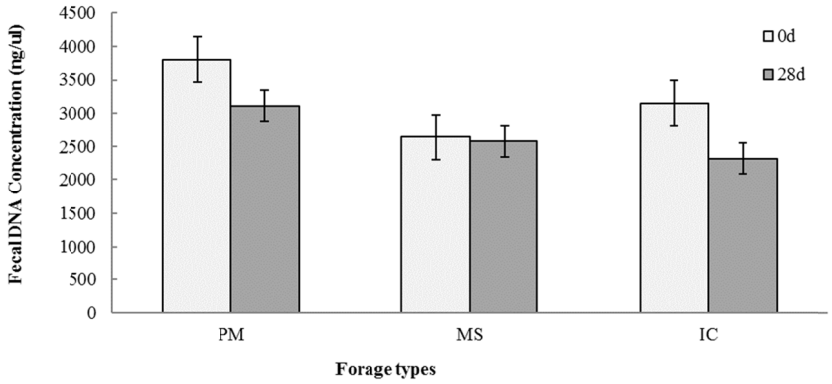


Figure 3. Fecal microbial DNA concentration in goats fed pearl millet (PM), Mississippi silver (MS), and Iron and Clay (IC) cowpea

*3.6 Serum Total Protein Concentration*

The average initial (day 0) serum protein concentration in goats was 908.52 mg/ml. Serum protein concentration was not affected by forage type grazed by the goats ($P = 0.1921$) as shown in Figure 4.

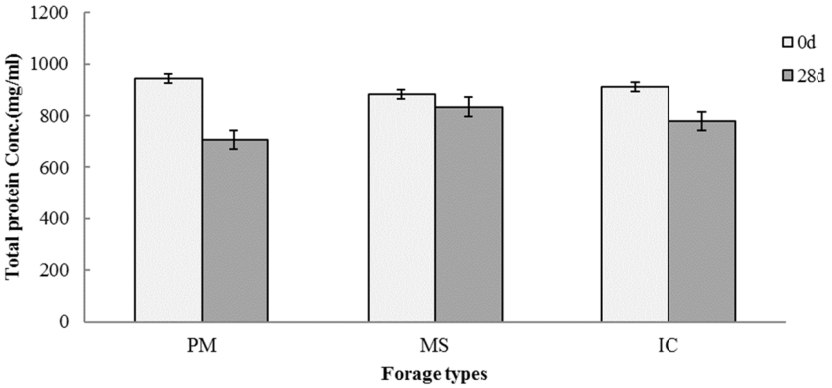


Figure 4. Total protein concentration in serum from goats fed Pearl Millet (PM), Mississippi silver (MS), and Iron and Clay (IC) cowpea

*3.7 PGE2*

Feed type treatment had no effect on PGE2 secreted levels, however, a significant time effect ($P < 0.05$) was observed. Overall the PGE2 concentration decreased from 585.43±69.65 ng/ml (0d) to 2.03±0.66 ng/ml (28 d) in the cowpea grazed goats.

*3.8 Effect of Cowpea Pasture on TAC*

The effect of cowpea pasture grazing on total antioxidant capacity in serum is presented in Figure 5. Serum TAC increased in both MS and IC grazed goats at 28 d compared to PM-grazed animals.

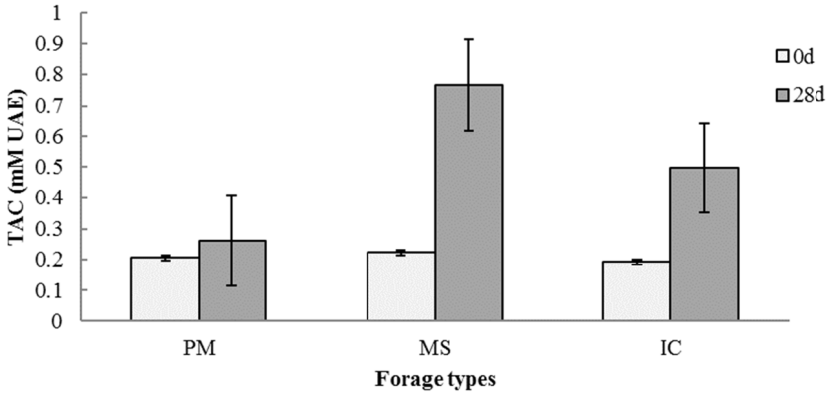


Figure 5. Total antioxidant capacity in serum of goats fed Pearl Millet (PM), Mississippi silver (MS), and Iron and Clay (IC) cowpea. Error bar represent SEM

*3.9 Correlation Results*

Association between phenotypic parameters measured is presented in Table 3. Body weight in goats positively correlated with BCS, TAC, % neutrophils count, and PGE2, but a weak negative correlation with FAMACHA score, total serum protein concentration, and % lymphocytes was observed. A strong negative association was observed between % lymphocytes counts and % neutrophils count ($r$ = -0.91; $r^2$ = -0.83). Total antioxidant capacity (TAC) was positively correlated with total serum protein concentration ($r$ = 0.38), % neutrophils count ($r$ = 0.35), and PGE2 ($r$ = 0.53), % lymphocytes count ($r$ = -0.40). However, there were no association between fecal egg count (FEC) and PCV, total protein, % lymphocytes, and PGE2.

Table 3. Correlation analysis between phenotypic parameters measured in goats

| | PCV | FAMACHA | TP | LYM | NEU | PGE2 | TAC | FEC | BCS | BW |
|---|---|---|---|---|---|---|---|---|---|---|
| PCV | 1 | | | | | | | | | |
| TP | 0.39 | -0.30 | 1 | | | | | | | |
| LYM | 0.087 | -0.097 | 0.25 | 1 | | | | | | |
| NEU | 0.064 | 0.041 | -0.13 | -0.91 | 1 | | | | | |
| PGE2 | 0.091 | -0.23 | 0.17 | -0.29 | 0.29 | 1 | | | | |
| TAC | 0.32 | -0.27 | 0.38 | -0.40 | 0.35 | 0.53 | 1 | | | |
| FEC | 0.049 | 0.29 | 0.045 | 0.057 | -0.15 | 0.0030 | 0.17 | 1 | | |
| BCS | -0.13 | -0.24 | 0.038 | 0.0086 | -0.19 | 0.27 | 0.25 | -0.24 | 1 | |
| BW | 0.13 | -0.16 | -0.10 | -0.26 | 0.15 | 0.34 | 0.17 | 0.053 | 0.30 | 1 |

*Note*. PCV: Packed cell volume; TP: Total protein concentration; LYM: Lymphocyte; NEU: Neutrophil; PGE2: Prostaglandin E 2; TAC: Total antioxidant capacity; FEC: Fecal egg count; BCS: Body condition score; BW: Body weight.

## 4. Discussion

In this study, the effect of freshly grazed cowpea forage on health and production parameters were evaluated in goats. Cowpea forage especially MS variety had an impact on growth and the health of the goats used in the study. Cowpea forage is nutritious (Sreerama et al., 2012), and therefore is comparable to other notable forage legumes such as alfalfa, soybean. Results from this study indicated high crude protein content in cowpea forage and this corroborates results from previous reports (Ishiaku, 2016; Katsande et al., 2016). In ruminant diet, protein is one of the major limiting nutrient (Gusha et al., 2014; Mapiye et al., 2014). Feed supplements that are able to correct this deficiency are necessary. Cowpea, as a feed resource is high in protein and phosphorus (Baloyi et al., 2008), and has been suggested as a suitable protein supplement to small ruminants on poor roughage diets (Etana et al., 2013). Also, leguminous forages including cowpea, compared to grasses and crop residues have high potential degradation and digestibility because it has low cell-wall content; and a high proportion of thin-wall non-lignified mesophyll tissues (Baloyi et al., 2008). Furthermore, theinclusion of

legume forages increases feed intake and especially cowpea forage has demonstrated a positive nitrogen balance in goats (Asaolu et al., 2011). Katsande et al. (2016) also observed a high nitrogen and microbial protein syntheses, which helps supply about two-thirds of the amino acid absorbed by ruminants (Pathak, 2008). Our study findings showed that goats grazed on cowpea forage had high growth performance than those on pearl millet , this was consistent with previous findings (Adeloye et al., 1995).

The experimental goats were healthy and no incidence of disease or infection were observed during the study period. Health parameters including PCV, FAMACHA, and WBC measured in the current study indicated no adverse effect of cowpea forage on goats. In addition to the nutritional constituents, cowpea forage contains phenolic compounds including flavonoid and tannins (Cai et al., 2003) that are beneficial for health. Cowpea forages analyzed in this study contained phenolic compound including tannins, and this result was similar to observations of previous studies (Adjei-Fremah et al., 2015; Ojwang et al., 2015). Katsande et al. (2016) reported about 1.2 g/kg DM tannin content in cowpea forage. Results from the current study showed that cowpea forage may have anthelmintic effect in goats as shown by reduction of FEC and fecal microbial DNA concentration. Previous studies have demonstrated the anthelmintic potentials of polyphenol-rich forages sulla (*Hedysarum coronarium*; Niezen et al., 1995), sericea lespedeza (*Lespedeza cuneata*; Min et al., 2004), sainfoin (*Onobrychus viciifolia*; Heckendorn et al., 2006), birdsfoot trefoil (*L. corniculatus*; Heckendorn et al., 2007). Sericea lespedeza, rich in condensed tannins reduced FEC (Min et al., 2004) when grazed as fresh forage (Terrill et al., 2009; Mechineni et al., 2014) and a similar observation was shown in the current study. Also, cowpea may impact gut health in goats as observed in reduction in microbial DNA levels (Qin et al., 2010; Malinen et al., 2005).

Results from the current study demonstrates the effect of cowpea forage grazing on markers of immunity and inflammation. In goats fed cowpea forage a lower PGE2 level in serum was observed. The production of proinflammatory cytokines is an essential component of the innate immune response, and they have the ability to activate neutrophils (Karcher et al., 2014; Koh et al., 2007). Prostaglandin E2, an eicosanoid is a mediator of inflammation. Reduction of serum PGE2 levels may suggest a possible anti-inflammatory action of cowpea feed in goats. The anti-inflammatory potential of cowpea seeds have been tested (Ojwang et al., 2015), and the anti-inflammatory effect of cowpea polyphenols in bovine blood have also been reported (Adjei-Fremah et al., 2017). Cowpea forage may, therefore, possess anti-inflammatory effects in goats due to the presence of polyphenols and their antioxidant potential and this requires further studies. Interestingly, the total antioxidant capacity in serum increased in cowpea grazed goats. Previous *in vitro* studies have shown the antioxidant capacity of cowpea polyphenol extract in the bovine blood (Adjei-Fremah et al., 2015), and cowpea's possible impact in combating oxidative stress in livestock. Worku et al. (2016), showed that diet may impact innate immune response biomarkers and gene expression in goats. Overall, the results from the present study suggest that cowpea forages have beneficial health effect in goats.

## 5. Conclusion

In conclusion, this study showed the production and health benefits of fresh cowpea forage grazing to goats. The MS cowpea forage especially increased body weight, decreased gastrointestinal parasite counts (FEC and fecal microbial DNA concentration), and modulated the concentration of biomarkers of immunity/inflammation including PGE2, and total antioxidant capacity in serum. Cowpea is a widely adapted and economical forage and results from this study suggest favorable benefits of integration of cowpea as a fresh forage into small ruminant feeding system. Further study is needed to understand the molecular impact, mechanism, and regulation of cowpea forage on immunity and inflammation in goats.

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