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Influence of *Garcinia kola* seed meal in diets of goats; Effect on rumen fermentation, nutrient utilisation, blood metabolites and faecal flora

Michael Igbaekemen Okoruwa and Onuwabhagbe Michael Edoror

Department of Animal Science, Ambrose Alli University, P.M.B. 14, Ekpoma, Nigeria

Correspondence Author: M.I. Okoruwa, Department of Animal Science, Ambrose Alli University, P.M.B. 14, Ekpoma, Nigeria.
E-mail:- odionokos@yahoo,com

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Abstract

Manipulation of the gut functions with feed additives has been recognized as an important strategy for improving performance and feed efficiency in goats. The purpose of the study was to determine the effect of *Garcinia kola* seed meal in diet supplements of goats; effect on rumen digestion, nutrient utilisation, blood metabolites and faecal flora. However, twenty-four West African dwarf male goats aged between 7 and 8 months old with mean live weight of 7.00 ± 0.38kg, were used in a completely randomized design for 84days. The goats were randomly allotted to four dietary treatments containing 0%, 2%, 4% and 6% of *Garcinia kola* inclusion levels. The 0% inclusion level served as the control group. Data obtained on rumen, metabolic and blood studies were analysed using one-way analysis of variance. Results obtained showed that rumen pH, total volatile fatty acids, ammonia nitrogen, acetate and propionate ratio, ether extract digestibility, nitrogen output, white blood cell, urea, cholesterol, feed intake and *E. coli* were significantly ($P < 0.05$) higher in GK_A than other diets. Acetate, butyrate, neutral and acid detergent fiber were higher ($P < 0.05$) than diets GK_A, GK_C and GK_D. Animals on GK_C were significantly ($P < 0.05$) superior in propionate, digestibility of crude protein, fiber and its fractions, with nitrogen free extract, nitrogen retention, packed cell volume, haemoglobin, red blood cell, total protein, glucose and weight gains. Nitrogen intake and lactobacilli were significantly ($P < 0.05$) higher in animals on GK_D. However, significant ($P > 0.05$) difference did not occur in rumen temperature, digestibility of dry matter with ash, albumin, globulin, creatinine, initial with final body weight, Enterobacteria, Coliforms bacteria and total bacteria load. It was concluded that goats fed diets containing 2% and 4%*Garcinia kola* inclusion levels had better rumen fermentation, nutrient utilisation, blood profile and faecal flora than those fed on 0% and 6% inclusion levels.

Keywords: *Garcinia kola*, rumen digestion, performance, blood, goats

INTRODUCTION

Though ruminant industry has become rapidly developing enterprise among other livestock sector in the tropics, their potential for returns on investment are jet to be fully improved. The negative effect of nutritional status that is characterized by insufficient feeds from poor quality forages and preponderance fibrous of crop residues are the major factors responsible for this challenge of low ruminant productivity in Nigeria. However, it has been apparent for many years that feeding standards based on assigned nutritive values are misleading when unconventional feed resources such as agricultural by-products are used (Okoruwa, 2019). A number of researchers (Jinadu*et al*., 2018; Akinfemi *et al*., 2012) observed that most of these agro by-products contain non-starch polysaccharide which is mostly non digestible carbohydrate that limits apparently bio-utilization of feeds in ruminants. This can lead to rejection of some feed resources and make achievement of goat productivity to be considerably less than the predicted level in the tropics. Notwithstanding, the relevance of goat feeding that is largely dependent on fibrous agro by-products and poor-quality forages that are deficient in nutrients particularly during the dry season have been questioned by most of the small ruminant farmers in socio-economic points of view (Aderemi and Nworgu, 2007). Thus, the nutritional quality of these high fiber feeds that accompanied with low digestible nutrient can be enhanced by goats through supplementation with plant bioactive secondary metabolites.

Plant seed meal has been widely advocated due to their reported widespread beneficial effects on livestock health and productivity (Patra and Saxena, 2000). Hence, supplementation with natural compounds from plants such as bitter kola (*Garcinia*

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kola) seed meal may manipulate high fiber diets to improve rumen digestion and other biological benefits in goats. *Garcinia kola* belongs to the family of *Guttiferae,* it has the ability to produce anti-microbial, antiviral, anti-inflammatory and antioxidant as medicinal benefits to livestock. It was noted in the previous study (Adegboye *et al.,* 2008) that *Garcinia kola has* some secondary metabolites which can give potential to act as digestibility enhancers and inhibit methane production by controlling the digestive pH, activity of digestive enzymes and microbial activity in the rumen. However, plant seed meal can also be used to modulate rumen ecology to improve its feed degradability and microbial efficiency by forming complexes with dietary protein in the rumen to prevent microbial fermentation and control ammonia with the help of nitrogen binding activity (Patra and Saxena, 2000). They have appetizing properties that stimulate the digestive system and promote feed utilization with better performance in ruminants. Thus, the objective of the study was designed to determine the effect of *Garcinia kola* seed meal in diet supplements of goats; effect on rumen fermentation characteristics, nutrient utilization, blood metabolites and faecal flora.

MATERIALS AND METHODS

Experimental site

The study was conducted at the small Ruminant Research Unit of the Teaching and Research Farm, Ambrose Alli University, Ekpoma. The area is located on longitude $6^0$09'East of the Greenwich meridian and latitude $6^0$42'North of the equator in the south-south geographical zone of Nigeria. The location has a prevailing tropical climate with a mean temperature and rainfall of about 31^0C and 1556mm respectively.

Preparation of diets

Fermented sorghum waste and groundnut shell were obtained from their processing center within Ekpoma, sundried, crushed and stored separately in air tight containers. Fresh *Garcinia kola* seeds were also purchased within Ekpoma, Edo state, Nigeria. They were sliced to increase their surface area, air dried for five days before milled into powder form and incorporated into supplement diets at different proportions of 0, 2, 4 and 6% respectively to designate four diets. The four comparative supplementary diets were; GK_A (22% fermented sorghum waste + 4% groundnut shell + 0% *Garcinia kola*), GK_B (18% fermented sorghum waste + 6% groundnut shell + 2% *Garcinia kola*), GK_C (14% fermented sorghum waste + 8% groundnut shell + 4% *Garcinia kola*),and GK_D (10% fermented sorghum waste + 10% groundnut shell + 6% *Garcinia kola*). Other feed gradients composition that comprised 40% wheat offal, 30% dried brewery grain, 2% calcium phosphate, 1% salt and 1% vitamin premix were also added to each of the supplementary diets (Table 1). Guinea grass was given to all the experimental animals as the basal diet. However, the experimental diets consisted of basal and supplementary diets which were given to goats in the ratio of 60:40 respectively. The control group which was diet GK_A received no *Garcinia kola* seed meal supplement. The gross and proximate compositions of the experimental diets are indicated in Table 1.

Table 1: Gross and proximate compositions (%) of experimental diets

Ingredients	Supplementary diets				Guinea grass
	GK_A	GK_B	GK_C	GK_D	
Wheat offal	40.00	40.00	40.00	40.00	–
Brewery dried grain	30.00	30.00	30.00	30.00	–
Fermented sorghum waste	22.00	18.00	14.00	10.00	–
Groundnut shells	4.00	6.00	8.00	10.00	–
Garcinia kola	0.00	2.00	4.00	6.00	–
Calcium phosphate	2.00	2.00	2.00	2.00	–
Salt	1.00	1.00	1.00	1.00	–
Vitamin	1.00	1.00	1.00	1.00	–
Total	100	100	100	100	–
Analysed composition					
Dry matter	84.93	86.75	90.07	92.03	89.05
Crude protein	12.89	13.11	13.45	13.98	6.98
Crude fibre	17.03	16.72	16.13	15.86	39.06
Ether extract	5.64	5.93	6.01	6.23	3.79
Ash	6.03	6.42	7.05	7.35	6.03
Nitrogen free extract	57.91	57.74	57.65	57. 37	53.87
Acid detergent fibre	31.58	33.43	35.36	35.48	49.37
Neutral detergent fibre	47.74	52.93	54.34	55.28	73.18
Acid detergent lignin	11.36	9.78	8.96	7.99	14.87

Animals, experimental design and feeding management

A total of twenty-four apparently healthy growing West African dwarf male goats, aged between 7 and 8 months old with a mean live weight of 7.00 ± 0.38 kg were selected from the general herds at small ruminant farm within Ekpoma. They were randomly divided into four treatment diets following a completely randomized design of six goats per treatment with each treatment replicated three times of two goats per replicate. After being weighed, identified by wooden tags, and subjected to the

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control of ecto and endo parasites, recommended vaccination and medication were adequately administered to enhance resistance to infections. The goats also underwent 14 days period of adaptation phase to familiarize them to the environmental condition. Thereafter, they were housed in 1.5m x 2.5m individual semi-opened pens that were equipped with feeding and watering facilities in an 84-day feeding trial and pens were cleaned daily.

Treatment diets were offered at 5% (dry matter) of their body weight twice daily at about 8:00am in the morning and 4:00pm in the evening. The amount of feed provided was adjusted after every two weeks according to bodyweight change. They were also having free access to water at all times. Weight of individual goat was measured at the onset of the study and subsequently on weekly basis with measuretech® hanging scale prior to feeding to determine change in body weight. The quantity of the feeds offered to goats and the residual feeds were weighed daily in the morning prior to the feeding to estimate daily feed intake.

Data collection and sampling procedures

Approximately 50 ml of rumen fluid samples were aspirated about 4 hours post morning feeding by suction tube thrust into the middle part of the rumen on day 10, 20, 30, 40, 50 and 60 of the feeding trails. After discarding the initial draw of 20 ml to minimize the contamination of saliva, the fluid was immediately measured for pH and temperature using a portable pH and temperature meter (HANNA instruments HI 8424 microcomputer, Singapore). The fluid samples were then filtered through four layers of cheesecloth, five milliliters of the fluid were mixed with chilled 25% meta-phosphoric acid (H_2PO_4) for volatile fatty acid (VFA) analysis, while 2 ml was mixed with 0.5M HCL for ammonia –N (NH_3-N) determination. The fluids were centrifuged at 15,000 xg for 20 minutes at 4^0C and supernatant was stored at -20^0C prior to ammonia nitrogen (NH_3-N) and VFA analyses. The NH_3-N content of the rumen fluid was determined by Chaney and Marbach (1962) modified to use a microtiter plate reader while VFA were separated and quantified by HPLC according to the report of Samuel *et al*. (1997).

Metabolic trail was conducted at the end of the 10^{th} week of the study to determine nutrient digestibility and nitrogen metabolism. The goats were acclimatized for 7 days before 7-day collection periods of faecal and urinary samples in the metabolic cages. Sub-samples of feed and feed residues were collected daily, dried and stored for subsequent analysis. Faeces were quantitatively collected by sterile disposable gloves immediately after an animal defecated during this period. The faeces collected each day were thoroughly mixed and sub-samples of about 5% were taken for dry matter determination and for storage at -20^0C. At the end of collection period, feed, feed residues and faecal samples from each animal were properly mixed, dried at 60^0C and ground through a 1mm screen in a mill prior to chemical analysis. The proximate composition of the feeds, leftover feeds and faecal samples were analyzed using the procedures of AOAC, (2002). Urine samples of about 50ml were also collected by spot sampling at approximately 6 and 12 hours after feeding for the 7 days of collection period. The daily urine samples were acidified by diluting 20 ml of urine with 80ml of 0.036M H_2SO_4 and stored at -20^0C until analyzed for nitrogen content (AOAC, 2002). Thus, apparent nutrient digestibility and nitrogen retention were calculated by standard procedures outlined for the direct estimation of animal digestibility (Crampton and Harris, 1969).

Part of the faecal sampled were also taken into sterile tubes kept cool before transfer to the laboratory. Selective medium assays were used to determine micro-organisms; plate count agar for total bacteria with incubation at 30 ± 2 ^{0}C for 48hrs; chromocult coliform agar for califorms and *E. coli* with incubation at 37 ± 2 ^{0}C for 24hrs; followed by incubation at 37 ^{0}C for 24hrs; De man Rogosa Sharpe agar for lactobacilli with incubation at 30 ± 2^0 C for 48hrs in microaerobic atmosphere and violet red bile glucose agar for enterobacteria with incubation at 30 ± 2^0C for 48hrs (Stella *et al.*, 2007).

At the end of the study before termination, two sets of blood samples were collected from individual goats through jungular vein puncture using 10ml hypothermic syringe with needle before morning feeding. The 5ml of the blood samples were introduced into the labeled sterile bottles containing ethylene diamine tretra acetic acid as anticoagulant for haematological determination using the Neubauerhaemocytometer after appropriate dilution as reported by Jain, (1993); Dacie and Lewis (2001). The other 5ml blood sampled was used for serum bio-chemical analysis. The serum was centrifuge at 400 rpm for 20 minutes thereafter; the blood sera were separated and preserved in clean and sterile bottles at-18^0C for subsequent bio-chemical analysis followed the procedures of Wermer*et al*. (1970).

Statistical analysis

Data that were collected from rumen digestion kinetics, nutrient utilisation, blood profile and faecal floral were subjected to Analysis of Variance (ANOVA), significant difference between means were separated using Duncan multiple range test (SAS, 2003).

RESULTS

The concentration of pH, temperature, ammonia nitrogen (NH_3 – N) and volatile fatty acid (VFA) with its fractions in the rumen fluid were used to determine rumen digestion kinetics (Table 2). Data on rumen pH, total volatile fatty acid (TVFA) and NH_3–N showed that dietary inclusion of *Garcinia kola* exert dominant control over the test diets (GK_B, GK_C and GK_D) by resulting in significantly ($P < 0.05$) lower mean values as compared with control diet (GK_A) value. Animals fed *Garcinia kola* at 2% inclusion level had significant ($P < 0.05$) higher proportions of acetate and butyrate, while those fed at 4% level of *Garcinia kola* were significantly ($P < 0.05$) higher in proportion of propionate than other diets. The ratio of acetate to propionate that were in optimal range between 2.60 and 3.90(mol/100ml) were significantly ($P < 0.05$) different, being higher in diets GK_A, GK_B and GK_D as compared with diet GK_C. However, rumen temperature mean values were unaffected by the treatment diets, hence significant difference ($P > 0.05$) was not observed.

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Table 2: Influence of *Garciniakola* on rumen digestion kinetics of goats

Parameters	GK_A	GK_B	GK_C	GK_D	SEM ±
pH	7.01^a	6.82^b	6.64^b	6.43^b	0.03
Temperature (^{0}C)	39.03	38.96	38.67	38.82	0.92
TVFA (mmol/L)	119.34^a	118.96^a	115.67^b	113.03^b	1.06
Acetate (mol/100mol)	78.01^b	80.06^a	76.69^b	77.95^b	0.75
Propionate (mol/100mol)	20.03^c	25.07^b	29.49^a	22.86^c	0.08
Butyrate (mol/100mol)	10.06^b	12.02^a	11.19^a	10.92^b	0.05
NH_3 – N (mg/dl)	22.29^a	17.29^b	17.03^b	16.99^b	0.34
Acetate: propionate ratio	3.90^a	3.19^a	2.60^b	3.41^a	0.05

[a,b,c] Means in the same row with different superscripts are significantly different "P < 0.05"
SEM = standard error of mean

Digestibility of nutrient parameters were affected by dietary source of *Garcinia kola* (Table 3) except dry matter and ash digestibility's that were not significantly (P > 0.05) influenced by inclusion levels of *Garcinia kola* in this current study. However, animals fed increased levels at 2 and 4% of *Garcinia kola* in the diets digested higher percentage of crude protein, fibre and nitrogen free extract than those fed at 0 and 6% levels of inclusion. Feeding control diet to animals significantly (P < 0.05) increased the digestibility of ether extract and reduced fiber fractions (ADF, NDF and ADL) digestibility in this study.

Data on nitrogen metabolism of goats is also shown in Table 3. Nitrogen intake increased progressively (P < 0.05) across the diets with increased in inclusion levels of groundnut shell. Faecal, urinary and total nitrogen output declined significantly (P < 0.05) at 2% and 4% inclusion levels of *Garcinia kola* as compared with inclusion levels of 0% and 6% in the diets. However, nitrogen retention in per day and as percentage intake were positively (P < 0.05) influenced by 2, 4 and 6% levels of *Garciniakola* inclusion than 0% level in the diets.

Table 3: Nutrient digestibility (%) and nitrogen metabolism of goats fed *Garciniakola* supplement

Parameters	GK_A	GK_B	GK_C	GK_D	SEM ±
Dry matter	87.26	88.34	88.93	87.98	0.93
Crude protein	68.95^b	85.21^a	86.99^a	84.99^a	1.06
Crude fibre	62.28^c	76.40^a	77.05^a	71.81^b	0.83
Ether extract	71.96^a	65.33^b	60.39^c	60.92^c	0.72
Ash	64.89	63.98	63.48	64.77	0.59
Nitrogen free extract	67.93^b	76.99^a	77.82^a	69.76^b	0.72
Neutral detergent fibre	63.89^c	81.39^a	79.99^a	68.78^b	0.62
Acid detergent fibre	65.34^b	72.01^a	71.21^a	71.45^a	0.47
Acid detergent lignin	58.22^c	65.46^b	69.03^a	63.63^b	0.93
Nitrogen Metabolism					
Nitrogen (N) intake (g/day)	9.16^a	9.84^b	10.09^a	10.21^a	0.67
Faecal N output (g/day)	3.53^a	1.96^b	1.45^b	2.83^b	0.05
Urinary N output (g/day)	1.83^a	1.12^{ab}	0.76^b	1.29^{ab}	0.03
Total N output (g/day)	5.36^a	3.08^b	2.21^b	4.12^a	0.10
N – retention (g/day)	3.80^b	6.76^a	7.88^a	6.09^a	0.42
N retention % intake	41.49^c	68.70^{ab}	78.10^a	59.65^b	0.79

[a,b,c] Means in the same row with different superscripts are significantly different "P < 0.05"
SEM = standard error of mean

Table 4: Effect of *Garcinia kola* supplementation on blood profile of goats

Parameters	GK_A	GK_B	GK_C	GK_D	SEM ±
Packed cell volume (%)	25.64^b	28.79^a	29.03^a	28.19^a	0.96
Haemoglobin (g/dl)	7.98^b	8.96^a	9.08^a	8.66^a	0.78
Red blood cell ($x10^6$/ml)	7.69^b	9.76^a	9.93^a	9.52^a	0.42
White blood cell ($x10^6$/ml)	11.65^a	8.52^b	8.76^b	9.84^b	0.56
Serum biochemical analysis					
Total protein (g/dl)	5.85^c	7.83^a	8.01^a	7.63^b	0.32
Albumin (g/dl)	2.93	3.59	3.66	3.47	0.09
Globulin (g/dl)	2.82	3.24	3.35	3.16	0.05
Urea (mg/dl)	25.93^a	20.11^c	20.06^c	22.65^b	0.63
Creatinine (mg/dl)	1.04	0.99	0.97	1.01	**0.02**

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Glucose (mg/dl)	58.99[c]	62.86[a]	64.03[a]	60.22[b]	1.02
Triglycerides (mg/dl)	168.12[a]	165.99[b]	162.03[c]	159.99[c]	1.64
Cholesterol (mg/dl)	59.63[a]	56.83[ab]	52.49[c]	40.93[c]	0.98

[a,b,c] Means in the same row with different superscripts are significantly different "P < 0.05"
SEM = standard error of mean

The results of blood chemistry analysis are shown in Table 4. Animals on test diets (GK_B, GK_C and GK_D) had somewhat higher significant (P < 0.05) values in packed cell volume (PCV), hemoglobin (Hb), red blood cell (RBC), Total protein and glucose than those on control diet (GK_A). However, parameters like white blood cell (WBC), urea, triglycerides and cholesterol increased significantly (P < 0.05) in animals on control diet compared with test diets. There were no significant (P > 0.05) differences for albumin, glubolin and creatinine in this study.

Table 5: Influence of *Garcinia kola* supplementation on growth and faecal flora (log10/g) of goats

Parameters	GK_A	GK_B	GK_C	GK_D	SEM ±
Initial body weight (kg)	7.99	7.12	6.87	7.52	0.03
Final body weight (kg)	9.95	10.18	10.52	10.03	0.19
Total weight gain (kg)	1.96[c]	3.06[a]	3.65[a]	2.51[b]	0.06
Daily weight gain (g/day)	22.33[c]	36.43[b]	43.45[a]	29.88[bc]	0.68
Daily feed intake (g/day)	199.86[a]	179.23[b]	170.29[b]	172.99[b]	1.34
Feed conversion ratio	8.38[a]	4.92[c]	3.92[c]	5.79[b]	0.07
Faecal floral (Log_{10}/g)					
Enterobacteria	5.76	5.34	5.25	5.22	0.39
Coliforms bacteria	4.38	4.23	4.34	4.25	0.21
Total bacteria load	7.82	7.74	7.69	7.57	0.36
E coli	2.15[a]	0.56[b]	0.53[b]	0.51[b]	0.03
Lactobacilli	3.82[b]	5.37[a]	5.59[a]	5.68[a]	0.41

[a,b,c] Means in the same row with different superscripts are significantly different "P < 0.05"
SEM = standard error of mean

Final body weight of goats mean values were not significantly (P < 0.05) affected by the dietary treatment (Table 5). Influence of *Garcinia kola* in the diets resulted in variations of total and daily weight gains. Animals on GK_B and GK_C recorded higher significant (P < 0.05) weight gains than those on GK_A and GK_D. However, feed intake was negatively (P < 0.05) affected as the inclusion levels of *Garcinia kola* gradually increased across the treatment diets. Feed conversion ratio that followed the trend as daily feed intake was significantly (P < 0.05) higher in control diet than the test diets. The microbiological assays of goats faecal floral are also indicted in Table 5. *Garcinia kola* supplementation did not affect faecal concentrations of *Enterobacteria*, *Coliform bacteria* and total bacteria load in the present study, hence their mean values did not differ between control and test diets significantly (P < 0.05). *E coli* were significantly (P < 0.05) lower in animals on test diets throughout the study period while *Lactobacillus* levels were higher.

DISCUSSION

In general, chemical composition data of the supplementary diets (Table 1) were high in dry matter and close in range for nutrient values, reflecting the relative proportion of the inclusion levels of the feed ingredients. However, the average crude protein (CP) value of 13.37% recorded in the diets were above the 10 to 12% CP moderate level required by ruminants for maximum growth (Gatemby, 2002). The recorded proximate composition value for guinea grass in this study was in agreement with the literature reported by FAO (2003).

Provision of *Garcinia kola* seed meal that contains bioactive secondary metabolites in the diets is an important factor for maintaining rumen health, dietary fiber and ferment-ability in goats. These factors are important in determining rumen pH, hence the inclusion of *Garcinia kola* seed meal in the diets could possibly responsible for the decreased in rumen pH values for animals on test diets as compared with those on control diet that had higher pH values. A higher rumen pH is reported to be favourable for bacteria adherence, an important perquisite for higher fermentation and fiber digestion that may probably lead to energy wastage (Palmonari *et al.*, 2010). The similar values observed in rumen temperature could be connected to the rate of heat evolution from rumen microbial fermentation activities. Evolution of heat has been used as an index for measuring the rate of rumen microbial fermentation activity (Okoruwa, 2015). Lack of *Garcinia kola* influence could explain why TVFA was higher in animals on control diet. Rumen TVFA was noted in literature to depend on factors like digestibility, rate of absorption, rumen pH, rate of digestion passage from rumen to other parts of the digestive tract as well as the activities of microbial population (Kholif *et al*., 2014). However, the difference in proportions of VFA fractions (acetate, propionate and butyrate) obtained could be linked to the difference in fermentation rate of neutral detergent fibre (NDF) and starch content in the diets (Wang and Wang, 2016). High degradability and solubility of crude protein in control diet (GK_A) could likely release more NH_3 – N in the rumen of the animals as compared with the test diets (GK_B, GK_C, GK_D,). This higher NH_3 – N concentration was associated with higher rumen TVFA which was indicator of higher fermentation rate of the control diet. On the other hand, the reduction of rumen NH_3 – N

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accumulation could reflect to the depression of microbial activity known as proteolytic bacteria related to the improvement of nitrogen retention in goats on test diets.

Addition of *Garcinia kola* seed meal to treatment diets did not influence the digestibility of dry matter and ash in this present study. The antimicrobial activity of *Garcinia kola* stimulates the secretion of endogenous digestive enzymes and juices of CP to improve the digestibility in animals. This reason might explain why the CP digestibility was positively affected by animals on the test diets. The fact that crude fiber and its fractions digestibility were higher in GK_B and GK_C would suggest that the modulation effects of *Garcina kola* levels of the diets favour the fiber digestion than GK_A and GK_D. This finding was consistent with Jinadu *et al*. (2018) who reported that rumen fibrolytic and celluloytic bacteria seem to be very sensitive to plant antimicrobial at a particular level to break fibrous feed constituents such as soluble and structural carbohydrate to provide energy for their own utilization and the host animals.

The gradual reduction in the digestibility of ether extract with increased levels of *Garcinia kola* inclusion indicate that the antimicrobial activity of the herbal caused an inhibition on microbes responsible for fats and oils fermentation process in the rumen of the animals. Better nitrogen free extract digestibility depends on the synchronous availability of protein and fiber digestibility in a diet, as proposed by Okoruwa (2019). Thus, the higher digestibility of protein and fiber in the test diets were the predominant factors contributing to the higher yield of nitrogen free extract in the test diets.

However, gradual increase in the trend of nitrogen intake in this study could be associated with increased in inclusion levels of groundnut shell in the diets. Notwithstanding, the lower faecal and urinary nitrogen output recorded in diets GK_B and GK_C could be connected to reduction in the number and diversity of hyperammonia producing bacteria, resulting in reduction rate of ammonia production from amino acid. This supports the reasoning of researcher (Kirisci and Kamalak, 2019) who suggested that plant extract exert their effect in nitrogen metabolism through the inhibition of proteolytic activity and prevention of attachment and colonization of feed by proteolytic bacteria which can reduce nitrogen excretion in animals. Furthermore, positive nitrogen retention in animals is related to high biological value of protein readily digestible and absorbable. The higher posted positive nitrogen retention in test diets could reflect the presence of optimum antimicrobial effect of *Garcinia kola* which delay rumen protein degradation by suppressing bacteria population that could have been responsible for the reduction of nitrogen retention (Jinadu*et al*., 2018)

Blood constituent's data recorded in this study were within the normal range of values for healthy goats (Daramola *et al.*,2005). Variation observed for PCV, Hb and RBC among diets explain the realistic evaluation of the nutritional qualities and diagnosis of health condition of the animals. Addition of *Garcinia kola* in the test diets could be an important factor that improved the parameters and health status of the animals. This is in accordance with the findings of Ogunleke *et al.* (2014) who noted that there is a relationship between nutritional status and blood profile and that protein deficiency can lead to clinical anaemia due to diseases of erythrocytes and hyper proteinemia. However, the slight increase in the immunity of animals on control diet could be attributed to the challenges from microbes' infection in the circulatory system of the goats due to absences of *Garcinia kola*.

The statistical similarities in the total protein values of the test diets indicate better quality of protein that was effectively utilities by the animals. This observation tally with the report of Kholif *et al*. (2014) that serum total protein reflects the nutritional status of animal and it has a positive collection with dietary protein quality utilization. The serum levels of albumin and globulin were unaffected by diets. The data clearly indicated no pathological lesions in the liver, since the liver is the main site of serum albumin synthesis. Serum glucose which is the indicator of plasma energy level did not change in test diets suggesting that the diets were better utilized to provide enough energy to support body weight gain (Table 5). The slight decreased for glucose in the control diet could be traceable to a greater individual variation in TVFA in the rumen (Table 2). Previous study (Stella *et al*., 2007) had shown that mobilization of adipose tissue resulting in variation of plasma glucose could occur when increase in animal performance is not supported by proper energy utilization. It is of interest that the test diets caused decrease in serum triglyceride and cholesterol concentration. The presence of *Garcinia kola* supplementation could probably be responsible for this lower serum fats and oil (Sahioul *et al*., 2010). Serum urea levels followed the same trend as rumen ammonia nitrogen concentration (Table 3). Rumen NH_3 – N enters the plasma urea pool after it has been absorbed into the blood and converted to urea by the liver. The higher value of plasma urea observed in control diet indicates inability of the animals to utilize nitrogen made available by rumen digestion. This inference also supported by the fact in the study of Kholif *et al.* (2014) that rumen ammonia nitrogen and blood urea may serve as effective indices of nitrogen utilization. It is interesting to also know that serum creatinine that is an indicator of glomerular filtration in the kidney was unaffected by diets. Serum urea and creatinine did not indicate catabolism of muscle protein; hence catabolism situation and kidney function were not adversely affected by the animals in this study. The influence of better nutrient density and quality of nutrient available for feed utilization and physiological state of animals on test diets might explain why animals on GK_B, GK_C and GK_D were higher in total and daily weight gains than those on GK_A. It has been evident that better feed quality diets with a possible increase in the digestibility provide better weight gain for animals (Santos *et al*., 2017). The observed trend in feed intake (Table 5) that decreased gradually with increased in *Garcinia kola* could be attributed to the palatability, physical and chemical forms of the diets. This fact is in consistent with previously published reports of Ogunleke *et al.* (2014) that factors such as dietary crude protein, palatability, gut fill, rumen outflow, and rate or retention time in the rumen affect feed intake in goats. Furthermore, animals on test diets were more efficient in converting feed to weight gain than those on control diet. Thus, the study could be ascribed to the more efficient utilization of feed by the animals on GK_B and GK_C as indicated in their lower feed conversion ratio.

The supplementation of *Garcinia kola* to diets also resulted in low number and diversity of *E. coli* levels. This indicates a reduction in the levels of the opportunist pathogen *E. coli*, not only through pH control but also receptor competition (Chaucheyras-Durand and Fonty, 2002) thereby improving the stability of the intestinal ecosystem. By contrast, *Lactobacilli* levels increased during the trial in animal faeces on test diets than those on control diet. The increased in *Lactobacilli* levels in

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animal faeces on test diets might be explained by inclusion of *Garcinia kola* that decreased *E. coli* and encouraged the production of *Lactobacilli* levels in the animals. The present result supports the report of Kirisci and Kamalak (2019) that reduction in rumen fermentation with herbal extract inclusion in diets may have several consequences in practice such as concomitant benefits from reduced methane production and increase beneficial rumen microbes. However, the levels of *Enterobacteria, Coliform* and total bacteria load observed were unaffected by *Garcinia kola* inclusion in the diets. Their present levels of concentration found in this current study were slightly lower than those reported by Stella *et al*. (2005).

CONCLUSION

This study demonstrates that *Garcinia kola* can be added on diets containing different proportions of fermented sorghum waste and groundnut shell for goats. The addition of *Garicinia kola* source did not affect rumen temperature, digestibility of ash, albumin, globulin, creatinine, *Enterobacteria and Coliforms* bacteria. Conversely, supply of *Garcinia kola* in the diets changed many of the study parameters. These changes occurred especially at 2 and 4% levels of *Garcinia kola* inclusion in the diets, which promoted decrease in rumen pH, NH_3 and fats content but increased rumen volatile fatty acids, digestibility, nitrogen metabolism, blood metabolites and weight gain with *Lactobacilli.*

Interestingly, it is more important to know that the inclusion of *Garcinia kola* in the diet of goats did not produce any adverse effect in the study. Hence, in conclusion results obtained in this study demonstrate positive effects of *Garcinia kola* seed meal on rumen fermentation, performance, blood profile and faecal flora of goats.

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