A mixed ration of crop residues: effects on rumen fermentation characteristics and blood indices of West African dwarf sheep

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Abstract

Crop residues are potential supplementary feed of small ruminants in Nigeria. However, arbitrary feeding of crop residues without due consideration to proportions and nutritive values could result in poor performance. Information on the proportions of mixed ration of different roughage sources for sheep is limited. Therefore, the effect of mixed ration of crop residues on the rumen fermentation and blood profiles of West African dwarf (WAD) sheep was investigated. Sixteen female WAD sheep with an average live weight of 8.10 ± 0.16 kg were used in a completely randomised design with four animals per treatment. Experimental diets (1 to 4) constitutes 53% each of corn cob, cassava peel, groundnut haulm and cowpea husk respectively, with 30% palm kernel sludge, 12% soya bean hull, 4.5% *Gliricidia sepium*, and 0.5% salt across each diet. The results revealed non-significant ($p > 0.05$) effects of experimental diets on rumen pH and volatile fatty acids. Rumen ammonia nitrogen differed significantly ($p < 0.05$), with the highest (10.17 mg/100mL) and lowest (8.51 mg/100mL) values in sheep fed dietary treatments 4 and 2, respectively. Bacteria counts were highest ($1.75 \text{ cfu/mL} \times 10^5$) in sheep fed diet 4 and lowest ($1.28 \times 10^5 \text{ cfu/mL}$) in sheep fed diet 3. Rumen fungi and protozoa counts were similar ($p > 0.05$) among treatment groups. Packed cell volume, haemoglobin, and red blood cell counts were highest (52.00 %, 16.95 g/dL and $14.25 \times 10^6/\mu\text{L}$) for sheep fed diet 4 and lowest (33.00 %, 10.65 g/dL and $11.79 \times 10^6/\mu\text{L}$) in sheep fed diet 1. While the white blood cell was significantly ($p < 0.05$) highest ($8.43 \times 10^3/\mu\text{L}$) in sheep fed diet 2, lymphocytes and neutrophils counts were similar ($p > 0.05$) among treatments. Serum biochemical components were significantly different ($p < 0.05$) among the treatments, except aspartate aminotransferase and creatinine. In conclusion, utilization of mixed ration of crop residues as feed did not compromise ruminal activities and the health of WAD sheep.

Keywords: Haematology and serum, roughage mixtures, rumen fermentation, sheep

Une ration mixte de résidus de culture : effets sur les caractéristiques de fermentation du rumen et les indices sanguins des moutons de West African Dwarf

Résumé

Les résidus de récolte sont des aliments complémentaires potentiels pour les petits ruminants au Nigeria. Cependant, une alimentation arbitraire des résidus de culture sans tenir dûment compte des proportions et des valeurs nutritives pourrait entraîner de mauvaises performances. Les informations sur les proportions de ration mixte de différentes sources de fourrage pour les moutons sont limitées. Par conséquent, l'effet d'une ration mixte de résidus de récolte sur la fermentation du rumen et les profils sanguins de moutons West African Dwarf (WAD) a été étudié. Seize moutons WAD femelles d'un poids vif moyen de $8,10 \pm 0,16$ kg ont été utilisés dans une conception complètement randomisée avec quatre animaux par traitement. Les régimes expérimentaux (1 à 4) contiennent respectivement 53 % de rafle de maïs, d'écorce de manioc, de fane d'arachide et de cosse de niébé, avec 30 % de

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boue de palmiste, 12 % de coque de soja, 4,5 % de *Gliricidia sepium* et 0,5 % de sel dans chaque régime. . Les résultats ont révélé des effets non significatifs ($p > 0,05$) des régimes expérimentaux sur le pH du rumen et les acides gras volatils. L'azote ammoniacal du rumen différait significativement ($p < 0,05$), avec les valeurs les plus élevées (10,17 mg/100 ml) et les plus faibles (8,51 mg/100 ml) chez les moutons nourris avec les traitements diététiques 4 et 2, respectivement. Le nombre de bactéries était le plus élevé ($1,75 \text{ cfu/mL} \times 10^5$) dans le régime 4 des moutons et le plus bas ($1,28 \times 10^5 \text{ cfu/mL}$) dans le régime 3. Le nombre de champignons et de protozoaires du rumen était similaire ($p > 0,05$) parmi les groupes de traitement. L'hématocrite, l'hémoglobine et le nombre de globules rouges étaient les plus élevés (52,00 %, 16,95 g/dL et $14,25 \times 10^6/\mu\text{L}$) pour les moutons nourris avec le régime 4 et les plus bas (33,00 %, 10,65 g/dL et $11,79 \times 10^6/\mu\text{L}$) chez les moutons régime alimentaire 1. Alors que le nombre de globules blancs était significativement ($p < 0,05$) le plus élevé ($8,43 \times 10^3/\mu\text{L}$) chez les moutons nourris avec le régime 2, le nombre de lymphocytes et de neutrophiles était similaire ($p > 0,05$) parmi les traitements. Les composants biochimiques du sérum étaient significativement différents ($p < 0,05$) parmi les traitements, à l'exception de l'aspartate aminotransférase et de la créatinine. En conclusion, l'utilisation d'une ration mixte de résidus de culture comme aliment n'a pas compromis les activités ruminales et la santé des moutons WAD.

Mots clés : Hématologie et sérum, mélanges de fourrages grossiers, fermentation ruminale, mouton

Introduction

Crop residues and agro-industrial by-products are alternate feed resources often utilized to salvage dry season feed challenges in ruminant production systems particularly in the Southwest agro-ecology zones of Nigeria. However, arbitrary feeding of crop residues as a supplement to ruminants in confinement by smallholder farmers without due consideration to the proportions and nutritive values could result in poor health status and performance. About 40-60% of the total dry matter intake of ruminants is from crop residues (Rao and Hall, 2003) but dietary nutrient utilization efficiency for growth, production or maintenance is limited. Reasons are because of the high fibre ($> 40\%$), low protein ($< 60\text{g/kg DM}$), low essential macro and micro minerals and low metabolizable energy ($< 7.5\text{MJ/kgDM}$) contents (Tingshuang *et al.*, 2002; Gulilat and Chekol, 2020). Nevertheless, methods of enhancing the effective utilization of fibres in crop residues-based diets by ruminants have been documented (Adesogan *et al.*, 2019). *In-vivo* and *in-vitro*

trials of tropical crop residues have shown higher organic matter digestibility and lower methane emission (Aregheore, 2000; Bhatt *et al.*, 2014) by small ruminants. Roughage diets from crop residues provide bulk for proper rumen function and fermentation of the fibres into useful volatile fatty acids components; a source of energy for rumen microbes and the host ruminants (Bergman, 1990; Nathani *et al.*, 2015). Cassava peel, cowpea husk, groundnut haulm and corn cob amongst others are notable crop residues widely utilized as low-cost roughage diets for small ruminants compared to the highly expensive grain-based concentrates. When any of these feed resources are ingested by small ruminants their physiological disposition to dietary nutrients can be evaluated via blood profiles. Similarly, the patterns of fermentation in the rumen *vis-à-vis* microbiota activities are plausible indicators of the efficiency or inefficiency of dietary nutrients for maintenance or production and overall health of the "host". According to Konka *et al.* (2016), crop residue-based complete ration in ruminant

feeding systems stabilizes ruminal fermentation, minimize fermentation losses and promotes the efficiency of ammonia utilization. Consequent to the arbitrary feeding of small ruminants with crop residues by smallholder farmers in Nigeria, rumen fermentation and blood profiles assays are necessary to diagnose the health status of animals reared under intensive husbandry systems. Therefore, a study was conducted to determine the effects of feeding different sources of roughages namely corn cob, cassava peel, groundnut haulms and cowpea husk on rumen fermentation, haematological and serum biochemical profiles of West African dwarf sheep.

Materials and methods

Location of study and animal management

The experiment was carried out at the sheep and goat unit of the Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria (latitude 7°15' to 7°30' North and longitude 3°45' to 4°0' East). The area has a tropical humid climate with a mean annual rainfall of 1415 mm and an average daily temperature of 28 and 35 °C. Before the commencement of the experiment, animals were given prophylactic treatments against ecto and endo-parasites. The animals were adapted to their treatment diets over a 2-week preliminary period, which was followed by a 105-day feeding trial. Sixteen West African Dwarf (WAD) female sheep with an average live weight of 8 ± 0.16 kg were weighed and randomly allotted to individual pens and one of four (4) treatment diets in a completely randomized design with four animals per treatment.

Experimental diets and feeding of animals

Dried cowpea husk, groundnut haulm, soya bean hull, cassava peel and corn cob were obtained from feedstuff vendors and crop processing unit of the Institute of

Agricultural Research and Training, Ibadan. *Gliricidia sepium* leaves were harvested fresh from an established pasture and air-dried under shade to about 25% dry matter. Four experimental diets were compounded to include each ingredient (Table 1) as follows; Diet 1= (53% Dried corn cob, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt), Diet 2= (53% Dried cassava peel, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt), Diet 3= (53% Groundnut haulm, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt) and Diet 4= (53% Cowpea husk, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt). Crop residue mixtures (Diet 1 to Diet 4) were offered separately to individual animals at 3% body weight at 08:00h. Unripe plantain peels were offered to all the sheep at 2% of their body weight at 16:00h. Provision was made for a daily feed allowance of 10% above the previous week's consumption. Clean water was served *ad libitum*.

Collection of rumen liquor samples and analysis

At the end of the experiment, rumen fluid samples (about 100 mL) were collected from the rumen of each sheep using stomach tubes into sterile sample bottles as described by Babayemi and Bamikole (2006) at 4 h post-feeding. The pH of the rumen fluid was recorded immediately after collection using a digital pH meter (3510 model pH meter, Jenway, UK). The rumen liquor was strained through 4 layers of sterile cheesecloth for separation of the liquid and solid fractions without any wash. The liquid fraction was divided into two portions. The first portion of the strained rumen fluids was acidified with 0.2 mol/L HCL solution and kept in labelled sample bottles stored at -20°C till required for volatile fatty acids and rumen ammonia nitrogen analysis. The second portion of the

rumen fluid was fixed with 10 % formalin solution (1:9 v/v, rumen fluid: 10 % formalin) and immediately kept in ice and stored at - 20 °C till further analyses of the microbial population. Rumen ammonia nitrogen (NH₃-N) concentration was determined by steam distillation and absorption in boric acid solution and later by titration with 0.1N H₂SO₄. Volatile fatty acids (VFA) concentrations were analyzed according to the procedure of Gilchrist (1967). Microbial population in the rumen fluids was by total direct count of bacteria, protozoan and fungal zoospores as described by Galyean (1989) and Dehority (2003).

Collection of blood samples and analysis

At the end of the experiment, two sets of blood samples (approximately 10mLs) were collected from each sheep before feeding through a jugular vein puncture using a 10mL syringe fitted with a hypodermic needle. Blood (5mLs) was drawn into labelled heparinized tubes to prevent coagulation for the determination of haematological parameters while the remaining 5mLs was drawn into anti-coagulant free bottles, allowed to coagulate at room temperature and centrifuged for 5 min at 3000 rpm for serum analysis. The supernatant sera were then stored in a freezer for subsequent biochemical analysis. The packed cell volume (PCV) was estimated by the method of Jain (1993), and haemoglobin (Hb) concentration according to the method of Schalm *et al.* (1975). Red blood cell (RBC), total white blood cell count (WBC) and differential WBC counts were determined using the Neubauer hemocytometer counting chamber. (MCHC) was calculated from RBC, Hb and PCV values as described by Dacie and Lewis (2001). Serum total protein was determined using the biuret method as described (Kohn and Allen, 1995). Albumin and globulin were determined using the bromocresol purple

method of Varley *et al.* (1980). Blood urea nitrogen and glucose were determined by an enzymatic colourimetric method (Helmut and Yvette, 1959) and the spectrophotometer was read at wavelengths of 550 nm and 600 nm, respectively. Creatinine was determined by the method of Bonsnes and Taussky (1945) while cholesterol was determined by the method of Allain *et al.* (1974). Alanine Aminotransferase (ALT), Aspartate Aminotransferase (AST) and Alkaline Phosphatase (ALP) were analyzed spectrophotometrically by using commercially available diagnostic kits (Randox® Test Kits).

Chemical analysis of feed

Dried samples of the experimental diets and unripe plantain peel were analyzed for the proximate composition according to the standard procedures (AOAC, 2000). Neutral detergent fibre, acid detergent fibre and Acid detergent lignin were determined according to the procedure of Van Soest *et al.* (1991). Metabolisable energy (ME) was estimated according to De Boever *et al.* (1997) equation as follows: ME = 12.86 + 0.0265 EE – 0.0056 ADF – 0.0153 ASH – 0.0253 ADL. Where EE = ether extract, ADF = acid detergent fibre and ADL = acid detergent lignin.

Statistical analyses

Data obtained were subjected to analysis of variance for a completely randomized design using the general linear model (PROC GLM) of SAS (1999). The least significant difference (LSD) statistics were used to identify differences among means. Differences among means were considered significant at a probability level of $p < 0.05$.

Results and discussion

Table 2 shows the chemical composition of the experimental diets. The dry matter (DM) and crude protein (CP) contents were highest (89.43 and 17.33 g/100g DM) in diet 4 and lowest (86.11 and 5.20 g/100g

DM) in diet 1. Except for the CP content of diet 1 (5.20g/100g DM), the range of CP (14.82-17.33g/100g DM) of diets 2 to 4 exceeded the CP level for sheep (NRC, 2007). Broken grains tightly held within the cowpea husk could have contributed to the higher (17.33 g/100g DM) CP content observed in diet 4. The ether extract ranged from 1.06 to 3.66g/100g DM. The ether extracts (1.06 to 3.66 g/100g DM) values of experimental diets in this study, which are below the range of 5-6% dietary fat that could negatively affect rumen microbial activity (Kucuk *et al.*, 2003) are

suggestive of being able to promote optimal ruminal fermentation activities. The fibre fractions (NDF, ADF and ADL) were highest (69.86, 48.94 and 17.43g/100g DM) in diet 1 and lowest (58.44, 41.35 and 12.67g/100g DM) in diet 3. The mean values of NDF (65.04g/100g DM) of experimental diets though were above the range (55-60g/100g DM) reported to limit feed intake (Meissner and Paulsmeier, 1995), the high fibre fractions of feed particle could also facilitate colonization of ingesta by rumen microbes to increase the rate of degradability (Klopfenstein *et al.*, 2001).

Table 1: Ingredient composition of experimental diets

Ingredients (%)	Dietary roughage treatments			
	Diet 1	Diet 2	Diet 3	Diet 4
Dried corn cob	53.0	-----	-----	-----
Palm kernel sludge	30.0	30.0	30.0	30.0
Soya bean hull	12.0	12.0	12.0	12.0
Dried cassava peel	-----	53.0	-----	-----
Groundnut haulm	-----	-----	53.0	-----
Cowpea husk	-----	-----	-----	53.0
<i>Gliricidia sepium</i>	4.5	4.5	4.5	4.5
Salt	0.5	0.5	0.5	0.5

Table 2: Chemical composition (g/100g DM) of experimental diets and unripe plantain peel

Nutrients	Dietary roughage treatments				Unripe plantain peel
	Diet 1	Diet 2	Diet 3	Diet 4	
Dry matter	86.11	88.50	88.35	89.43	87.17
Crude protein	5.20	15.34	14.82	17.33	5.42
Ash	5.78	4.71	4.30	5.90	4.37
Ether extract	1.06	2.94	2.85	3.66	3.20
Neutral detergent fibre	69.86	62.91	58.44	68.95	51.37
Acid detergent fibre	48.94	43.06	41.35	47.81	39.57
Acid detergent lignin	17.43	13.35	12.67	15.08	11.44
Metabolizable energy	12.12	12.29	12.27	12.22	12.37
(MJ/kg DM)					

Diet 1= 53% Dried corn cob, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 2= 53% Dried cassava peel, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 3= 53% Groundnut haulm, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 4= 53% Cowpea husk, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt.

Rumen fermentation characteristics and microbial population

Presented in Table 3 are the results of rumen fermentation characteristics and microbial population of sheep fed mixed ration of crop residues. The rumen pH showed no significant ($p>0.05$) difference across the treatments. Observed rumen pH values (6.05 to 6.20) in this study are within the normal pH range of 5.5 to 7.0 (Krause and Oetzel, 2006) considered as appropriate for microbial digestion of fibre and proteins in ruminants largely fed roughages. Consumption of high levels of dietary fibres by ruminants increases the buffering capacity of the rumen due to stimulation of saliva production in the buccal cavity (Kohn and Dunlop, 1998; Aschenbach *et al.*, 2011). The experimental diets in this study, being highly fibrous could have stimulated constant salivation during rumination to produce bicarbonates and phosphates into the rumen for maintenance of optimal ruminal pH in the experimental animals. Ammonia nitrogen concentration in the rumen is a function of protein quality and its degradability. The rumen ammonia nitrogen ($\text{NH}_3\text{-N}$) concentration obtained in this trial ranged from 8.51 to 10.17 mg/100mL. Significantly ($p<0.05$) highest rumen $\text{NH}_3\text{-N}$ concentration (10.17 mg/100mL) observed in sheep fed diet 4 may be linked with the high crude protein content of the diet (Table 2) and crude protein digestibility (Ajayi *et al.*, 2019), probably due to a more functional rumen that allowed rapid ruminal fermentation of dietary proteins. As a qualitative reference for the detection of microbial activity in structural carbohydrates in the rumen (Detmann *et al.*, 2009), Leng (1990) reported that ruminal $\text{NH}_3\text{-N}$ concentrations of 5-20 mg/100mL are required for enhanced microbial activity and digestion by ruminants fed poor quality roughages or fibrous feed. It could be inferred that ruminal $\text{NH}_3\text{-N}$ concentrations (8.51-10.17

mg/100mL) observed in this study fell within the range of 5-20 mg/100mL (Leng, 1990), thus were adequate for ruminal fermentation activities. The concentrations of total volatile fatty acids (TVFAs), acetic, propionic and butyric acids were similar ($p>0.05$) across the treatments. Meanwhile, TVFAs, acetic, propionic and butyric acid values were highest in sheep fed diet 4 and lowest in sheep fed diet 1. The fermentable carbohydrates of the principal ingredients (cassava peel and cowpea husk) in diets 2 and 4 respectively, could have attributed to the higher values of TVFAs observed in sheep fed the respective diets. Meanwhile, the highest concentration of TVFA, acetic, propionic and butyric acids observed in sheep fed diet 4 compared to other treatments further indicates the higher degradability potential of the nutrients. The proportions of VFAs in this study disagreed with the findings of Firkins *et al.* (2006) who reported a higher concentration of acetic acid and a low amount of propionic and butyric acids in the rumen for high fibre diets. The non-significance of ruminal VFAs concentrations across the treatments may be ascribed to dietary fibre components (e.g. Neutral detergent fibre), substrate composition, specific types of rumen microbes to degrade the diets consumed (Haddad and Grant, 2000) and the rumen pH values which favour bacterial adherence for enhanced digestion of fibres (Palmonari *et al.*, 2010). Except for sheep fed diet 2, the higher concentration of butyric acid relative to acetic and propionic acids suggest nutrient utilization efficiency (Li *et al.*, 2012), which may have impacted positively on the growth performance of the sheep (Ajayi *et al.*, 2019). Although specific butyrate-producing bacteria or protozoa species were not identified, higher rumen butyric acid concentration relative to acetic and propionic acids in this study are associated with protozoa counts. This agreed with the findings of Carberry *et al.*

(2006) who reported that ruminal protozoa populations have a positive relationship with the levels of butyric acid. Total bacteria counts were significantly highest ($1.75 \text{ cfu/mL} \times 10^5$) in sheep fed diet 4 and lowest ($1.28 \times 10^5 \text{ cfu/mL}$) in sheep fed diet 3. Corn cob and cowpea husk (major roughage components of diets 1 and 4, respectively) though very high in fibre, are highly fermentable structural carbohydrates which when ruminally degraded could have resulted in the higher bacteria count observed in sheep fed dietary treatments 1 and 4, respectively. Rumen fungi count were relatively similar ($p > 0.05$) across treatment groups, except for the marginal numerical differences of fungi count between sheep fed diets 2 ($0.30 \times 10^5 \text{ cfu/mL}$) and 3 ($0.23 \times 10^5 \text{ cfu/mL}$), respectively. The variation in numerical fungi count between sheep fed diets 2 ($0.30 \times 10^5 \text{ cfu/mL}$) and 3 ($0.23 \times 10^5 \text{ cfu/mL}$), respectively is a reflection of differences in

diets resistance to the reduction in the size of the feed particles for attachment of bacteria and digestion of structural cell walls (Castilo-Gonzalez *et al.*, 2014). Rumen protozoa count was similar ($p > 0.05$), with a mean population ranging from 3.75 to 4.75 ml/100mL across the treatment groups. The variation in rumen protozoa population among dietary treatments may be from the dietary levels of starch (Brown *et al.*, 2006) and the rate of starch fermentation (Carberry *et al.*, 2012). The proliferation of rumen microbes for rapid degradation of roughages or fibrous feed is a function of ruminally fermentable dietary nutrients in the ruminal ecosystem (Newbold and Ramos-Morales, 2020). As a result, differences in total microbial biomass in this study could be ascribed to the suitability of the substrate available in the ruminal ecosystem for the proliferation of the microbes.

Table 3: Rumen fermentation characteristics and microbial population of sheep fed mixed ration of crop residues

Parameters	Dietary roughage treatments				SEM	P-value
	T1	T2	T3	T4		
Rumen pH	6.14	6.05	6.20	6.17	0.03	0.2679
Total volatile fatty acids (mmol/mL)	134.75	258.50	157.00	269.50	27.21	0.1848
Acetic acid (mmol/mL)	89.50	172.00	105.25	179.50	18.17	0.1897
Propionic acid (mmol/mL)	1111.3	2109.5	1296.0	2219.0	222.86	0.1906
Butyric acid (mmol/mL)	1805.0	1398.0	1543.0	2642.8	304.10	0.5152
NH ₃ -N (mg/100mL)	9.61 ^{ab}	8.51 ^c	9.28 ^b	10.17 ^a	0.17	0.0004
Bacterial count (cfu/mL $\times 10^5$)	1.65 ^a	1.53 ^a	1.28 ^b	1.75 ^a	0.06	0.0047
Fungi count (cfu/mL $\times 10^5$)	0.28 ^{ab}	0.30 ^a	0.23 ^b	0.28 ^{ab}	0.01	0.1522
Protozoa count (ml/100mL)	4.00	3.75	4.50	4.75	0.17	0.1382

^{abc}= Means on the same row with different superscript differ significantly ($p < 0.05$).

Diet 1= 53% Dried corn cob, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 2= 53% Dried cassava peel, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 3= 53% Groundnut haulm, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 4= 53% Cowpea husk, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt.

Haematological parameters

Haematological parameters of sheep fed mixed ration of crop residues are shown in Table 4. There were significant ($p < 0.05$) differences across the treatments, except for the lymphocytes and neutrophils which were similar. The PCV (52.00%) and (Hb) (16.95g/dL) values of sheep fed diet 4 were above the normal range (27-45% and 9-15g/dL). However, the range of PVC (33.00-45.00%), Hb (10.65-14.65g/dL) and RBC ($11.79-14.2 \times 10^6/\mu\text{l}$) of sheep fed diets 1, 2 and 3, respectively were within the normal range (27-45%, 9-15g/dL and $9-15 \times 10^6/\mu\text{l}$), reported by Radostits *et al.* (2007) for clinically healthy sheep. The high packed cell volume (PCV), haemoglobin (Hb), red blood cell (RBC) values observed in this study is an indication of the absence of anaemic condition and active erythropoiesis across all the experimental sheep. The higher Hb and PCV values above the normal physiological range observed for sheep fed diet 4 may not directly indicate a relative polycythaemic condition as observed from the relationship between PCV and haemoglobin (MCHC). Although dietary and serum copper (Cu) levels were not assayed, the range of Hb and RBC values observed across the treatment groups may be from the residual Cu content in palm kernel sludge, a component of the diets. Palm kernel sludge is a by-product of palm kernel cake processing during palm kernel oil extraction. Palm kernel cake is relatively high in copper and iron (Duduyemi *et al.*, 2016). Therefore, the Cu content in the diet may have contributed to the formation of red blood cells. Functional roles of serum copper among others are in erythropoiesis and production of copper-containing mitochondrial proteins for haem synthesis (Williams *et al.*, 1985).

The white blood cell was highest ($8.43 \times 10^3/\mu\text{l}$) in dietary treatment 2 and lowest ($6.55 \times 10^3/\mu\text{l}$) in sheep fed diet 4. The lymphocytes and neutrophils count varied

from 59.50 - 63.50% and 32.50 - 35.00%, respectively across the treatments. The non-significance of WBC, lymphocyte and neutrophil counts of experimental animals across the treatments, which are within the normal physiological ranges (WBC= 5.00 to $11.00 \times 10^6/\text{dL}$, lymphocytes= 40-75% and neutrophil= 10-50%) reported for healthy sheep (Scott *et al.* 2006; Radostits *et al.*, 2007), implies that the sheep had similar immune response against infections. Further attested by the high lymphocytes and neutrophils is also an indication of a well-developed immune system that is capable of fighting infections and the presence of foreign bodies in the circulatory system. Sheep fed tannin-rich feeds have been implicated in the reduction of WBC and white blood cells differential counts (Mahgoub *et al.*, 2008). The lymphocyte and neutrophil counts observed in this study are suggestive that the experimental diets did not contain toxic or anti-nutritional substances that could result in low WBC count.

Serum biochemical profiles

Serum biochemical values were significant ($p < 0.05$), except aspartate aminotransferase (AST) and creatinine that were similar ($p > 0.05$) (Table 5). Serum total protein across the treatments ranged from 8.68 to 9.78 g/dL and were significantly different ($p < 0.05$). In this study, serum total protein of 8.68 to 9.78 g/dL was not comparable to values of serum protein (6.4 to 8.3 and 5.81 to 6.36 g/dL) reported for Nigerian and Ethiopian breeds of sheep respectively (Njidda *et al.*, 2014; Ayele *et al.*, 2017). Serum protein above the normal range (6.0-7.9 g/dL) reported by Kaneko *et al.* (2008) among the sheep might be attributed to greater efficiency of dietary protein utilization. Albumin values among sheep fed diets 1 to 3 respectively, were within the normal range of 2.4-3.0 g/dL reported by Kaneko *et al.* (2008). Serum albumin is a highly sensitive and nutritional

Table 4: Haematological parameters of sheep fed mixed ration of crop residues

Parameters	Dietary roughage treatments				SEM	P-value
	T1	T2	T3	T4		
Packed cell volume (%)	33.00 ^b	43.50 ^a	45.00 ^a	52.00 ^a	2.29	0.0116
Haemoglobin (g/dL)	10.65 ^b	14.20 ^a	14.65 ^a	16.95 ^a	0.78	0.0163
Red blood cells (x10 ⁶ /μl)	11.79 ^b	12.84 ^{ab}	13.29 ^a	14.25 ^a	0.31	0.0174
MCHC (%)	32.27	32.64	32.56	32.60	0.07	0.2069
White blood cells (x 10 ³ /μl)	7.40 ^{ab}	8.43 ^a	6.65 ^b	6.55 ^b	0.27	0.0272
Lymphocytes (%)	63.50	62.00	59.50	61.00	0.99	0.5786
Neutrophils (%)	32.50	33.50	34.00	35.00	0.79	0.7686

^{abc}= Means on the same row with different superscripts are significantly different (p<0.05).

MCHC= Mean corpuscular haemoglobin concentration. Diet 1= 53% Dried corn cob, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 2= 53% Dried cassava peel, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 3= 53% Groundnut haulm, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 4= 53% Cowpea husk, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt.

indicator of protein status (Agenas *et al.*, 2006) and predisposition of animals to diseases. Interestingly, higher serum protein levels observed is an indication of the absence of proteinuria and hypoproteinemia (Kaneko *et al.*, 2008). The higher albumin value (4.36 g/dL) observed for sheep fed diet 4 though was above the normal value as reported (Kaneko *et al.*, 2008), might be indicative of the synthetic ability of the liver and the crude protein (17.33%), which is above the 14.48% CP recommended for growing sheep (NRC, 2007). Globulin level of sheep fed diet 4 (5.42g/dL) was statistically similar (p>0.05) to the value (6.19 g/dL) recorded for dietary treatment 3. The varied serum globulin levels (5.42 to 6.92 g/dL) which is above the normal physiological range (3.5-5.7 g/dL) prescribed by Kaneko *et al.* (2008), except for sheep on diet 4 (5.42g/dL) is suggestive of the absence of malnutrition and congenital immune deficiency (Busher 1990) among the experimental animals. Serum glucose concentration of sheep fed diet 2 (94.83 mg/dL) and diet 4 (61.21 mg/dL) agrees with the normal ranges of 55.0-131.00 mg/dL and 50-80 mg/dL reported by Radostits *et al.* (2007) and Latimer (2011),

respectively. However, high serum glucose concentration observed in sheep fed diets 2 and 4 respectively, does not suggest hyperglycemia condition as they are within the reported normal range (Radostits *et al.*, 2000; Latimer, 2011). Meanwhile, the significantly lower blood glucose levels detected in sheep fed diets 1 (32.68 mg/dL) and 3 (41.38 mg/dL), respectively, compared to the normal range could be a manifestation of carbohydrate deficiency. The hypoglycemic condition could also be associated with a lower rate of recovery of glucose (Radostits *et al.*, 2000). It follows that significant variations in serum glucose levels observed across the treatment groups may be reflective of the dietary energy levels, intake and metabolism by individual animals. The range of cholesterol levels (15.50-22.39 mg/dL) among the treatments was below the normal ranges of 43-103 mg/dL and 52-76 mg/dL reported by Radostits *et al.* (2007) and Kaneko *et al.* (2008) respectively. The extremely low cholesterol levels compared to the reference range of 52 - 76 mg/dL (Kaneko *et al.*, 2008) implies that experimental animals were healthy and not vulnerable to myocardial infarctions caused by the blockage of walls of blood vessels. Therefore, crop residues

A mixed ration of crop residues

based diets for ruminants, being low in soluble carbohydrates and energy could reduce the deposition of fats in tissues. The creatinine concentrations (1.45-2.00 mg/dL) across the treatments were within the normal range (1.00-2.00 mg/dL) reported by Banerjee (2006) but disagreed with 1.61-1.89 mg/dL reported for sheep by Jiwuba *et al.* (2017). The creatinine levels observed across the treatments are indicative of normal renal function, which could have resulted from efficient protein and amino acid metabolism (Abu El-Ella and Kommonna, 2013), absence of tissue protein catabolism (Prvulovic *et al.*, 2012) and anti-nutritional factors in the diets. The serum urea values ranged from 20.62 to 23.49 mg/dL across the treatments and falls within the normal range (10-35 mg/dL) reported by Radostits *et al.* (2000). Meanwhile, serum urea values in this study were not in agreement with the range (11.73 to 18.24 mg/dL) of serum urea values

reported by Alves *et al.* (2014) who evaluated diets with increasing levels of urea in sheep feeding. Within the normal range of serum urea observed in this study is an indication of efficient utilisation of dietary nitrogen (Alves *et al.*, 2014). However, higher serum urea nitrogen observed in sheep fed diet 1 despite the low crude protein content (5.20g/100g DM) may be a result of the increased catabolic activity for increased gluconeogenesis or excessive tissue protein breakdown (Radostits *et al.*, 2000). Serum enzyme activity can be used to predict the severity of injury to hepatic cells. In this study, the low levels of serum activity of liver enzymes (ALT, AST and ALP), below normal physiological ranges reported (Radostits *et al.*, 2000; Kaneko *et al.*, 2008; Latimer, 2011) implies that no hepatocellular damage occurred in the animals. This is an indication of no toxic effect of experimental diets upon ingestion by the animals on the liver or muscles due to optimal renal and hepatic functions.

Table 5: Serum parameters of sheep fed mixed ration of crop residues

Parameters	Dietary roughage treatments				SEM	P-value
	T1	T2	T3	T4		
Total protein (g/dL)	9.61 ^a	9.06 ^b	8.68 ^b	9.78 ^a	0.14	0.0033
Albumin (g/dL)	2.69 ^b	2.42 ^b	2.49 ^b	4.36 ^a	0.23	0.0002
Globulin (g/dL)	6.92 ^a	6.64 ^a	6.19 ^{ab}	5.42 ^b	0.21	0.0331
ALT (IU/L)	7.80 ^b	8.48 ^b	9.92 ^a	8.64 ^b	0.23	0.0011
AST (IU/L)	21.31	24.00	26.13	20.69	1.11	0.2947
ALP (IU/L)	52.43 ^c	64.25 ^a	53.94 ^{bc}	59.24 ^{ab}	1.50	0.0049
Cholesterol (mg/dL)	22.39 ^a	15.46 ^b	22.16 ^a	16.14 ^b	1.05	0.0051
Glucose (mg/dL)	32.68 ^d	94.83 ^a	41.38 ^c	61.21 ^b	6.23	<.0001
Creatinine (mg/dL)	1.55	1.80	2.00	1.45	0.09	0.1301
Urea (mg/dL)	23.49 ^a	20.62 ^b	21.48 ^b	20.89 ^b	0.39	0.0201

^{abc}= Means on the same row with different superscript differ significantly (p<0.05).

AST= Aspartate aminotransferase; ALT= Alanine transferase; ALP= Alkaline phosphatase. Diet 1= 53% Dried corn cob, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 2= 53% Dried cassava peel, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 3= 53% Groundnut haulm, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt; Diet 4= 53% Cowpea husk, 30% Palm kernel sludge, 12% Soya bean hull, 4.5% *Gliricidia sepium* and 0.5% Salt.

Conclusion

The study revealed that crop residues based-diets from different roughage sources influenced ruminal fermentation characteristics of sheep as evidenced in the ruminal ammonia nitrogen concentration and microbial counts higher in rumen protozoan. Also, butyric and propionic acids were of higher proportions than acetic acid in the rumen. Haematological and serum biochemical parameters were similar to normal reference values for apparently healthy sheep. Therefore, mixed ration of crop residues have no negative impact on the ruminal activities and health of West African dwarf sheep and can be strategically utilised as dry season feed in smallholder sheep production system.

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