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ORIGINAL RESEARCH ARTICLE

Evaluation of dietary malted sorghum sprout treated with polyethylene glycol on the performance of West African dwarf goats

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ABSTRACT

A twelve-week trial was conducted to investigate the influence of dietary malted sorghum sprout treated polyethylene glycol-6000 (MSP + PEG-6000) on the performance of West African dwarf (WAD) goats. MSP was treated with PEG-6000 molecular weight at ratio: 1kg to 1g and then incorporated into the diets at varying levels of 0%, 20%, 40% and 60% (MSP + PEG-6000) to formulate four dietary treatments. *Panicum maximum* leave was provided as the basal diet along with the compounded dietary treatments, and were given free access to fresh, cool clean water. Twenty (20) WAD goats were divided into four dietary treatments on weight equalization, each consisting of five goats, in a completely randomized design. Data collected on the performance of WAD goats were subjected to one-way ANOVA. Results revealed that dietary MSP + PEG-6000 had no significant (p>0.05) influence on all the growth parameters observed except the concentrate dry matter intake (CDMI) and the feed conversion ratio (FCR). Similar CDMI values were obtained in goats fed 20% MSP+PEG-6000 (3359.50g/d) and 40% MSP+PEG-6000 (3359.60g/d) but significantly (p<0.05) recorded the highest values. Goats fed dietary 40% MSP+PEG-6000 had the best FCR (4.60) value. The nutrient intake parameters obtained were significantly (p<0.05) influenced by the dietary MSP+ PEG-6000. Goats on dietary MSP+PEG-6000 had higher concentrate crude protein intake values when compared with those on control diet. Goats fed 20% and 40% MSP+PEG-6000 recorded similar (p>0.05) concentrate DM, ash and hemicellulose intake values but significantly (p<0.05) higher when compared with other dietary treatment. Dietary MSP+ PEG-6000 significantly (p<0.05) influenced all nutrient digestibility (ND) values observed in this study. Goats fed 40% MSP+PEG recorded the highest ND values. Dietary MSP+PEG-6000 significantly (p<0.05) influenced the nitrogen utilization (NU) parameters across the dietary treatments except the urinary nitrogen output. Goats on 40% MSP+PEG-6000 had the highest NU values (77.82%) when compared with other dietary treatments. Dietary MSP+PEG-6000 significantly (p<0.05) influenced all the rumen fermentation parameters except the acetic/ propionic ratio. Goats fed 40% MSP+PEG-6000 based diet recorded the highest propionic acid (42.00mm/100mL), acetic acid (42.50mm/100mL), butyric acid (33.50 mm/100mL), total volatile fatty acids (118.00mm/100mL), total bacterial count (2.85 x 10^6cfu/mL) and total coliform count (1.45 x10^6 cfu/mL). It can be concluded that MSP treated with PEG-6000 can be incorporated into goat's diet up to 40% inclusion level as it improved the overall performance of the experimental goats.

Keywords: Malted sorghum sprout, Microbial fermentation, Tannin-binding agent, Anti-nutrient, Livestock, West African dwarf goat, Chevon

INTRODUCTION

Nutrition is one of the most important factors affecting animal production in most parts of the world. Ruminants in the tropics suffer from scarcity of good quality pasture mostly during the dry season when natural vegetation is of poor quality value (Ososanya *et al.*, 2013). Goat meat simply referred to chevon is thought to be a highly nutritious diet that provides a considerable source of iron and protein for humans (Webb, 2014). As a result, goat meat has grown economically significant on a global scale (Naumann *et al.*, 2017). However, shortage of feed supply due to seasonality and high cost had prompted livestock farmers to search for alternative feed resources that can economically supplement the feed ingredients without any adverse effect on the rumen microbial fermentation and performance of the animals (Aka *et al.*, 2011). Malted Sorghum Sprout (MSP) is a by-product of the sorghum malting process; it is the separated root and shoots that are left over after the malt is extracted from the young, germinating seedlings, and it has alot of potential as a feed ingredient in the livestock industry (Aletor *et al.,* 1998). According to Saka *et al.* (2016), MSP has the following compositions: 88.79% dry matter, 26.38% crude protein, 2.35% ether extract, 5.21% ash, 51.06% nitrogen-free extract, 49.57% neutral detergent fibre, 31.25% acid detergent fibre, 3.92% acid detergent lignin, 18.32% hemicellulose, 27.33% cellulose and highly rich in organic nitrogen. Although, there is presence of anti-nutritional factors diminishing animal productivity which may also cause toxicity during periods of scarcity or confinement when the feed rich in this substance is consumed in large quantities. Multipurpose tanniferous species-containing diets have been proposed as a dependable alternative for protein supplements or as the only source of feed (Yisehak *et al.* 2012, 2014). Multipurpose tanniferous species have been employed to improve animal intake and production, lessen rumen acidity and other health-related issues, and ameliorate crude protein (CP) deficit in fibrous feeds (Yisehak *et al*., 2012). However, multipurpose tanniferous species may have significant limitations to their application due to the existence of secondary plant chemicals, such as condensed tannins (CT) (Lamy *et al.* 2011). Condensed tannin (CT) supplements at high concentrations (>50 g CT/kg dry mass (DM) have been examined for many years (Makkar, 2003) and are generally thought to have detrimental effects on ruminant nutrition. Therefore, polyethylene glycol is an inert unabsorbed molecule that can form stable complexes with tannins, preventing the binding between tannins and proteins and can even displace protein from a preformed tannin-protein complex (Makkar, 2003; Frutos *et al.,* 2004). Polyethylene glycol is a good tannin-binding agent; offer a viable technique to enhance the nutritive value of tannin-rich trees and shrubs (Singh *et al.,* 2005; Nsahlai *et al.*, 2011). In this regard, the available protein present in malted sorghum sprout can be effectively utilized. Therefore, the current study was designed to assess the influence of dietary malted sorghum sprout treated with polyethylene glycol-6000 on the performance of West African dwarf goats.

MATERIALS AND METHODS

Experimental site and duration: The experiment was conducted at the Teaching and Research Farm of Federal College of Animal Health and Production Technology, Moor Plantation, Ibadan and it lasted for a period of twelve weeks (84 days).

Sourcing and processing of the test ingredients

Malted sorghum sprout was purchased from Life Care Agro-allied Industry in Sango-Otta, Ogun State. While, Seglo Nigeria Limited in Ibadan, Oyo State, Nigeria provided the polyethylene glycol (PEG) that was used in this study. According to Ben Salem *et al.* (2000) procedure, the Malted Sorghum Sprout was treated with PEG-6000 molecular weight at 1kg to 1g, which was then incorporated into the experimental diet at varying levels of 0%, 20%, 40%, and 60%, respectively, to formulate four (4) dietary treatments T_1, T_2, T_3 and T_4

Table 1: Gross composition of the experimental diet

	Inclusion levels of MSP+PEG-6000			
Ingredients	0%	20%	40%	60%
Maize	14.00	14.00	14.00	14.00
Maize bran	20.25	20.25	20.25	20.25
Wheat offal	60.00	40.00	20.00	0.00
MSP+PEG	0.00	20.00	40.00	60.00
Premix	0.25	0.25	0.25	0.25
Limestone	5.00	5.00	5.00	5.00
Salt	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00
Determined analysis				
Dry matter	86.11	86.12	86.23	86.12
Crude protein	13.64	14.92	17.04	19.73
Ether Extract	3.70	2.70	2.21	2.61
Ash	8.70	8.59	8.87	8.59
NFE	49.09	50.10	47.31	45.99
NDF	71.80	67.95	62.82	57.05
ADF	15.38	12.18	6.41	6.41
ADL	4.33	4.00	3.00	4.00
Cellulose	11.05	8.18	3.41	2.41
Hemicellulose	56.42	55.77	56.41	50.64

NFE**:** Nitrogen Free Extract, NDF**:** Neutral Detergent Fibre, ADF**:** Acid Detergent Fibre, ADL**:** Acid Detergent Lignin, MSP: Malted Sorghum Sprout, PEG: Polyethylene glycol

Experimental animals, their management and design

Twenty (20) West African dwarf goats were used for this study. The pens were cleaned with morigad, scrubbed, and disinfected before the animals arrived. On the arrival of the animals, they were given prophylactic treatment containing oxytetracycline (Long Acting) antibiotic and vitamin B-complex through intra-muscular route at the dosage rate of 1mL/10kg body weight to prevent infections that are proven or strongly suspected and help keep the animals in good health condition. Ivermectin was also administered to the animals in order to control endoparasites and ectoparasites. *Pestis des Petits Ruminants* (PPR) vaccine was given subcutaneously at 1 mL per 10kg body weight to prevent PPR disease. The animals were acclimatized for four weeks before the onset of the experiment and during the period, guinea grass (*Panicum maximum*) and fresh cool, clean, water was served *ad libitum*. After the adaptation period, the experimental animals were balanced as closely as possible for their body weights into four dietary treatments in a completely randomized design.

RESULTS

Influence of dietary Malted sorghum sprout treated with polyethylene glycol-6000 on performance characteristics of West African dwarf goats

Presented in Table 2 is the influence of dietary malted sorghum sprout treated with polyethylene glycol-6000 on the growth performance of West African dwarf goats. Dietary malted sorghum sprout treated with polyethylene glycol-6000 (MSP+PEG-6000) had no (p>0.05) influence on the growth performance of WAD goats except the concentrate dry matter (CDMI) and feed conversion ratio (FCR). Similar CDMI values were obtained in goats fed 20% MSP+PEG-6000 (3359.50g/d) and 40% MSP+PEG-6000 (3359.60g/d) but significantly (p<0.05) recorded the highest values followed by those fed 60% MSP+PEG-6000 (2795.10g/d) and 0% MSP+PEG-6000 (1918.10 g/d). Goats fed dietary 40% MSP+PEG-6000 had the best FCR (4.60) value.

Table 3 shows the influence of dietary malted sorghum sprout treated with polyethylene glycol on the serum biochemical indices of West African Dwarf goats. Dietary malted sorghum sprout treated with polyethylene glycol (MSP+PEG-6000) had no significant (p>0.05) influence on serum biochemical indices of West African dwarf goats except blood urea nitrogen (BUN) and aspartate aminotransferase (AST). BUN values observed in this study increased across the dietary treatments as the MSP+PEG-6000 inclusion levels increased. The highest AST value was observed in goats fed 0% (21.81 U/L) and 60% (25.65U/L) MSP+PEG-6000 when compared with other dietary treatments.

Influence of dietary malted sorghum sprout treated with polyethylene glycol on the haematological indices of West African dwarf goats

Indicated in Table 4 is the influence of dietary malted sorghum sprout treated with polyethylene glycol (MSP+PEG-6000) on the haematological indices of West African dwarf goats. No significant (p>0.05) influence were observed on all the haematological indices measured in this study.

Influence of dietary malted sorghum sprout treated with polyethylene glycol on the Nutrient intake of West African dwarf goats

Table 5 shows the influence of dietary malted sorghum sprout treated with polyethylene glycol on the nutrient intake of West African dwarf goats. Dietary malted sorghum sprout treated with polyethylene glycol (MSP+PEG-6000) had no significant difference (p>0.05) on the nutrient intake values except the concentrate intake values.

Table 2: Influence of dietary malted sorghum sprout treated with polyethylene glycol-6000 on Performance characteristics of West African dwarf goats

	Inclusion levels of MSP + PEG-6000				
Parameters	0%	20%	40%	60%	SEM
Initial Weight (kg)	5.93	5.23	5.54	6.31	0.33
Final Weight (kg)	6.72	5.85	7.09	6.68	0.32
Weight Gain (kg)	0.80	0.62	1.55	0.38	0.22
ADWG (g/d)	12.62	9.76	24.52	5.95	3.47
Conc. Dry Matter Intake (g/d)	1918.10^{b}	3363.50^{a}	3359.60^{a}	2795.10^{ab}	254.82
Forage Dry Matter Intake (g/d)	3386.90	2904.10	3746.20	3710.40	294.78
TFI (g/d)	5305	6268	7106	6505	407.87
ADFI (g/d)	84.21	99.49	112.79	103.26	6.47
FCR	6.67^{bc}	10.19^{ab}	4.60^{c}	17.35^{a}	1.90

^{a,b} means along the same row with different superscripts are significantly different (p<0.05). MSP: Malted Sorghum Sprout, ADWG: Average daily weight gain, TFI: Total Feed Intake, ADFI: Average Daily Feed Intake, PEG: Polyethylene glycol

Table 3: Influence of dietary malted sorghum sprout treated with polyethylene glycol on the Serum biochemical indices of West African dwarf goats

	Inclusion level of MSP + PEG-6000					Normal Range
Parameters	0%	20%	40%	60%	SEM	
Total Protein (g/dL)	6.67	6.39	6.58	6.11	0.23	6.3 – 8.5[1]
Albumin (g/dL)	2.13	2.70	2.07	2.04	0.15	2.7 – 3.8[2]
Globulin (g/dL)	4.54	3.69	4.51	4.07	0.26	3.72 – 4.32[3]
BUN (mg/dL)	16.58[b]	17.15[b]	18.40[ab]	20.58[a]	0.63	8 – 26[6]
Glucose (mg/dL)	15.38	17.55	14.45	13.52	0.86	48 – 76[3]
AST (µ/L)	21.81[a]	14.53[ab]	13.63[b]	25.65[a]	2.17	12 – 38[4]
ALT(µ/L)	24.64	24.34	24.49	25.84	0.27	15 – 52[3]
ALP(µ/L)	44.16	44.16	44.17	44.16	0.00	27 – 300[3]

[a,b] means along the same row with different superscripts are significantly different ($p<0.05$). MSP: Malted Sorghum Sprout, [1]Reference ranges by Daramola *et al.* (2005), [2]Reference ranges by Feldman *et al.* (2002), Reference ranges by Merck Veterinary Manual, [3]2011; [4]2016, [5]Reference ranges by Opara *et al.* (2010), [5]Reference ranges by Babeker and Elmansoury (2013)

The highest concentrate dry matter intake value was recorded in goats fed 20% MSP+PEG-6000 (46.55g/d) and 40% MSP+PEG-6000 (46.49g/d) having similar values while the lowest value was obtained in goats fed 0% MSP+PEG-6000 (23.61g/d). Goats fed dietary MSP+PEG-6000 recorded higher concentrate crude protein intake values when compared with those in control. Goats fed 20% MSP+PEG-6000 (1.26g/d) based diet had the highest ether extract intake value followed by those on 30, 40 and 0% MSP+PEG-6000 respectively. Concentrate Ash intake values observed in this study varied significantly from 2.05 to 4.12g/d in which goats fed 20 and 40% MSP+PEG-6000 had similar values but higher than those on 0 and 60% MSP+PEG-6000. The concentrate NDF (31.63g/d), ADF (5.67g/d), ADL (1.86g/d) and cellulose (3.18g/d) intake were significantly highest in goats fed 20% MSP+PEG-6000 (33.60g/d). Goats fed 20 (25.96 g/d) and 40% (26.23g/d) MSP+PEG-6000 based diet had statistically similar concentrate hemicellulose intake values but higher than those fed 0 and 60 % MSP+PEG-6000.

Influence of dietary malted sorghum sprout treated with polyethylene glycol on the nutrient digestibility of West African dwarf goats

Indicated in Table 6 is the influence of dietary malted sorghum sprout treated with polyethylene glycol on the nutrient digestibility of West African dwarf goats**.** Dietary malted sorghum sprout treated with polyethylene glycol (MSP+PEG-6000) significantly ($p<0.05$) influenced all the nutrient digestibility parameters investigated. Goats fed diet containing 40% MSP+PEG-6000 recorded the highest dry matter (78.06 %), crude protein (83.44 %), ash (87.83 %), ether extract (88.04 %), neutral detergent fibre (87.13%), acid detergent fibre (88.94 %), acid detergent lignin (60.72%), hemicellulose (87.44%) and cellulose (86.28%) while those fed diets containing 60% MSP+PEG-6000 recorded the lowest values in all the parameters observed.

Influence of dietary malted sorghum sprout treated with polyethylene glycol on the nitrogen utilization of West African dwarf goats

Presented in Table 7 is the influence of dietary malted sorghum sprout treated with polyethylene glycol on the nitrogen utilization of West African dwarf goat. Addition of malted sorghum sprout treated with polyethylene glycol (MSP+PEG-6000) significantly ($p<0.05$) influenced the nitrogen utilization parameters obtained in this study except nitrogen losses in urine.

Table 4: Influence of dietary malted sorghum sprout treated with polyethylene glycol on the haematological indices of West African dwarf goats

Parameters	Inclusion levels of MSP+PEG-6000 (%)					Normal Range
	0%	20%	40%	60%	SEM	
Packed Cell Volume (%)	29.00	24.50	30.25	26.00	1.44	21 - 35[2]
Haemoglobin (g/dL)	9.65	8.45	10.28	8.60	0.05	7 - 15[2]
Red Blood Cell ($\times 10^4$)	10.31	10.21	11.46	10.48	0.28	8 - 18[1]
White Blood Cell ($\times 10^3$)	8.45	8.43	9.13	8.60	0.35	4-13[0]
Platelet ($\times 10^4$)	59.25	53.75	55.45	55.85	1.61	>100
Lymphocyte (%)	66.00	64.00	71.00	62.00	2.06	50-70[1]
Neutrophil (%)	30.99	32.00	28.00	35.00	1.92	30-48[1]
Monocytes (%)	2.00	1.50	2.50	1.00	0.30	0-4[1]
Eosinophil (%)	2.00	2.50	2.00	2.00	0.30	1-7[2]

[a,b] means along the same row with different superscripts are significantly different ($p<0.05$)[0]Reference range by Feldman *et al.* (2002), [1]Reference range by Fielder (2016), [2]Reference range by Daramola *et al.* (2005). MSP: Malted Sorghum Sprout, PEG: Polyethylene glycol

Table 5: Influence of dietary malted sorghum sprout treated with polyethylene glycol on the nutrient intake of West African dwarf goats

	Inclusion levels of MSP + PEG-6000				
Parameters (g/d)	0%	20%	40%	60%	SEM
Dry Matter Intake					
Concentrate	23.61^{b}	46.55^{a}	46.49^{a}	37.53^{ab}	4.04
Forage	45.33	37.67	51.04	50.47	4.68
Total	68.94	84.22	97.53	88.00	6.47
Crude Protein Intake					
Concentrate	3.22^{b}	6.95^{a}	7.92^{a}	7.41^{a}	0.77
Forage	3.45	2.86	3.88	3.84	0.36
Total	6.66	9.81	11.80	11.24	0.92
Ether Extract Intake					
Concentrate	0.64^{b}	1.26^{a}	1.03^{ab}	0.98^{ab}	0.09
Forage	0.78	0.65	0.88	0.87	0.08
Total	1.42	1.91	1.91	1.85	0.12
Ash Intake					
Concentrate	2.05^{b}	4.00^{a}	4.12^{a}	3.22^{ab}	0.36
Forage	1.93	1.60	2.17	2.14	0.20
Total	3.98	5.60	6.29	5.37	0.43
NDF Intake					
Concentrate	16.95^{b}	31.63^{a}	29.21^{ab}	21.41^{ab}	2.55
Forage	34.34	28.53	38.66	38.23	3.54
Total	51.29	60.17	67.87	59.64	4.38
ADF Intake					
Concentrate	3.63^{b}	5.67^{a}	2.98^{b}	2.43^{b}	0.50
Forage	27.20	22.60	30.62	30.28	2.81
Total	30.83	28.27	33.60	32.71	2.70
ADL Intake					
Concentrate	1.02^{b}	1.86^{a}	1.39^{ab}	1.50^{ab}	0.13
Forage	12.92	10.74	14.55	14.38	1.33
Total	13.94	12.60	15.94	15.88	1.34
Cellulose Intake					
Concentrate	2.61^{b}	3.81^{a}	1.59^{c}	0.90^{c}	0.43
Forage	14.28	11.87	16.08	15.90	1.47
Total	16.89	15.67	17.66	16.80	1.39
Hemicellulose Intake					
Concentrate	13.32^{b}	25.96^{a}	26.23^{a}	19.01^{ab}	2.30
Forage	7.14	5.93	8.04	7.95	0.74
Total	20.46	31.90	34.26	26.96	2.47

^{abc} means along the same row with different superscript are significantly different (p<0.05) NFE: Nitrogen Free Extract, NDF: Neutral Detergent Fibre, ADF: Acid Detergent Fibre, ADL: Acid Detergent Lignin, MSP: Malted Sorghum Sprout, PEG: Polyethylene glycol

Table 6: Influence of dietary malted sorghum sprout treated with polyethylene glycol on the nutrient digestibility of West African dwarf goats

Parameters	Inclusion levels of MSP+ PEG-6000 (%)				
	0%	20%	40%	60%	SEM
Dry matter	66.84^{ab}	65.26^{ab}	78.06^{a}	63.75^{b}	1.67
Crude Protein	73.91^{ab}	69.93^{ab}	83.44^{a}	63.42^{b}	1.48
Ether extract	78.28^{ab}	77.82^{ab}	88.04^{a}	72.29^{b}	1.38
Ash	74.65^{b}	72.31^{b}	87.83^{a}	66.45^{b}	1.11
NDF	76.64^{b}	73.34^{b}	87.13^{a}	69.45^{ab}	1.63
ADF	82.80^{b}	83.21^{b}	88.94^{a}	79.72^{ab}	1.63
ADL	50.01^{ab}	42.19^{b}	60.72^{a}	40.67^{b}	1.30
Hemicellulose	74.21^{b}	71.36^{b}	87.44^{a}	57.93^{c}	1.40
Cellulose	81.80^{b}	78.14^{b}	86.28^{a}	73.71^{ab}	1.05

^{a,b} means along the same row with different superscripts are significantly different (p<0.05), MSP: Malted Sorghum Sprout, PEG: Polyethylene glycol, NDF: Neutral Detergent Fibre, ADF: Acid Detergent Fibre, ADL: Acid Detergent Lignin

Table 7: Influence of dietary malted sorghum sprout treated with polyethylene glycol on the nitrogen utilization of West African dwarf goats

	Inclusion levels of MSP + PEG-6000				
Parameters (%)	0%	20%	40%	60%	SEM
N intake (g/d)	1.07^{b}	1.57^{ab}	1.88^{a}	1.80^{a}	0.42
N Output (Faeces)	0.18^{b}	0.14^{b}	0.03^{b}	0.41^{a}	0.05
N output (Urine)	0.25	0.58	0.38	0.40	0.06
Total N Output	0.43^{b}	0.72^{ab}	0.41^{b}	0.81^{a}	0.07
N Balance	0.63^{b}	0.85^{ab}	1.48^{a}	0.99^{ab}	0.15
N Utilization (%)	59.36^{ab}	54.37^{b}	77.82^{a}	52.85^{b}	1.85

^{a,b,c} means with different superscript letters along the same row are significantly different ($p<0.05$), N: Nitrogen

The nitrogen losses in faeces and nitrogen retention values obtained in this study did not follow a particular trend but ranged from 0.03-0.41 g/d and 52.85-77.82 % respectively. The nitrogen intake (1.07-1.88 g/d), nitrogen losses in urine (0.25-0.58 g/d), total nitrogen output (0.41-0.81 g/d) and nitrogen retention (52.85-77.82 %) significantly increased across the dietary treatment as MSP+PEG-6000 increased. Goats fed 40% MSP+PEG-6000 recorded the highest nitrogen intake (1.88 g/d), nitrogen balance (1.48 g/d) and nitrogen retention (77.82 %) value but recorded the lowest nitrogen losses values in urine (0.38 g/d) and faeces (0.03 g/d) compared to other dietary treatments.

Influence of dietary malted sorghum sprout treated with polyethylene glycol on the Rumen fermentation parameters of West African dwarf goats

Presented in Table 8 is the influence of dietary malted sorghum sprout treated with polyethylene glycol on the Rumen fermentation parameters of West African dwarf goats. Dietary malted sorghum sprout treated with polyethylene glycol (MSP+PEG-6000) had significant ($p<0.05$) influence on the rumen fermentation parameters investigated except the acetic/propionic ratio. Rumen pH values obtained in this study varied significantly across the dietary treatments. Goats fed dietary 20% (6.49) and 60% (6.50) MSP+PEG-6000 had statistically similar values but significantly higher than those fed 0% (6.39) and 40% (6.28) MSP+PEG-6000 respectively. Rumen ammonia nitrogen recorded in this study were significantly ($p<0.05$) influenced by dietary MSP+PEG-6000. Thus, highest ammonia nitrogen value (10.35mg/100mL) was obtained in goats fed 40% MSP+PEG-6000, followed by those on 60% MSP+PEG-6000 (9.68mg/100mL), 20% MSP+PEG-6000 (8.73mg/100mL) and 0% MSP+PEG-6000 (8.03mg/100mL) respectively. Goats fed 60% MSP+PEG-6000 (30.00mm/100mL), 20% MSP+PEG-6000 (32.00mm/100mL) and 0% MSP+PEG-6000 (32.50mm/100mL) had statistically similar ($p>0.05$) propionic acid values but significantly lower than the values obtained in goats fed 40% MSP+PEG-6000 (42.00mm/100mL). Addition of MSP+PEG-6000 significantly ($p<0.05$) influenced the acetic, butyric and total volatile fatty acid values in which goats fed 40% MSP+PEG-6000 had the highest values 42.50 mm/100mL, 33.50 mm/100mL and 118.00 mm/100mL respectively. The lactic acid values obtained in goats fed dietary MSP+PEG-6000 were higher than the values obtained in control.

Influence of dietary malted sorghum sprout treated with polyethylene glycol on the microbial counts of West African dwarf goats

Presented in Table 9 is the influence of dietary malted sorghum sprout treated with polyethylene glycol on the microbial counts of West African Dwarf goats. Dietary malted sorghum sprout treated with polyethylene glycol (MSP+PEG-6000) had significant ($p<0.05$) effect on the microbial count

Table 8: Influence of dietary malted sorghum sprout treated with polyethylene glycol on the Rumen fermentation parameters of West African dwarf goats

Parameters	Inclusion levels of MSP+ PEG-6000 (%)				
	0	20	40	60	SEM
Rumen pH	6.39^{ab}	6.49^{a}	6.28^{b}	6.50^{a}	0.03
Rumen NH_3-N (mg/100mL)	8.03^{c}	8.73^{bc}	10.35^{a}	9.68^{ab}	0.27
Propionic acid (mm/100mL)	32.50^{b}	32.00^{b}	42.00^{a}	30.00^{b}	1.37
Acetic acid (mm/100mL)	31.00^{c}	36.00^{b}	42.50^{a}	33.50^{bc}	1.44
Butyric acid (mm/100mL)	22.45^{b}	23.15^{b}	33.50^{a}	15.23^{c}	1.83
Total Volatile fatty acids (mm/100mL)	84.95^{bc}	91.15^{b}	118.00^{a}	78.73^{c}	4.04
Acetic/ Propionic	0.94	1.13	1.01	1.12	0.04
Lactic acid (mm/100mL)	20.75^{b}	29.00^{a}	31.50^{a}	33.50^{a}	1.64

^{a,b} means along the same row with different superscripts are significantly different ($p<0.05$). MSP: Malted Sorghum Sprout, PEG: Polyethylene glycol, NH_3-N: Ammonia nitrogen

Table 9: Influence of dietary malted sorghum sprout treated with polyethylene glycol on the microbial counts of West African dwarf goats

Parameters	Inclusion levels of MSP + PEG-6000(%)				
	0	20	40	60	SEM
TBC (x10^6 cfu/ml)	2.08^b	2.73^a	2.85^a	2.75^a	0.11
TCC (x10^6 cfu/ml)	0.60^c	0.95^{bc}	1.45^a	1.13^{ab}	0.10
TFC (x10^6 cfu/ml)	0.23^b	0.24^b	0.25^b	0.41^a	0.02
Protozoan (x10^6 cfu/ml)	5.73^a	6.13^a	3.63^b	4.80^{ab}	0.33

[a, b, c] means along the same row with different superscripts are significantly different ($p<0.05$)

TCC: Total Coliform Count, TBC: Total Bacterial Count, TFC: Total Fungal Count, MSP: Malted Sorghum Sprout, PEG: Polyethylene glycol

values obtained in this study. Goats fed dietary MSP+PEG-6000 recorded the higher total bacterial count (TBC) values when compared with values obtained in control. Total coliform count was highest in goats fed 40% MSP+PEG-6000 (1.45 x10^6cfu/mL), followed by those on 60% MSP+PEG-6000 (1.13 x10^6cfu/mL), 20% MSP+PEG (0.95x10^6cfu/mL) and 0% MSP+PEG (0.60 x10^6cfu/mL) respectively. Higher total fungal count was obtained in goats fed 60% MSP+PEG-6000 (0.41x10^6cfu/mL) when compared with other dietary treatments; 40% MSP+PEG (0.25x10^6cfu/mL), 20% MSP+PEG (0.24x10^6cfu/mL) and 0% MSP+PEG (0.23x10^6cfu/mL) having statistically similar values. Goats fed 0% (5.73 x10^6cfu/mL) and 20% MSP+PEG (6.13x10^6cfu/mL) had similar protozoan counts but significantly recorded the highest, followed by those on 60% MSP+PEG-6000 (4.80x10^6cfu/ml) and 40% MSP+PEG-6000 (3.63x10^6cfu/ml) respectively.

DISCUSSION

Performance characteristics

Feed intake is a measure of diet appreciation, selection and consumption by an animal (Masafu, 2006). It is a key process which determines the quantity of feedstuff ingested over a period of time, usually per day (Kroes *et al.,* 2002). The most significant aspect influencing animal performance is nutrient intake (McDonalds *et al.,* 1995). Significantly higher concentrate dry matter intake values observed in goats fed 20 and 40% MSP+PEG-6000 may be an indication of the palatability of the concentrate diet consisting MSP+PEG-6000. This observation was in accordance with result of Bhatta *et al.* (2002) who reported 26% increase in voluntary intake of *Prosopis* leaves in kids drenched with 5 g PEG. This is also similar to the observations of Silanikove *et al.* (2001) who reported higher voluntary consumption of *Prosopis* leaves supplemented with PEG-6000 in goats. The lowest feed conversion ratio (4.60) obtained in goats fed dietary 40% MSP+PEG-6000 could be attributed to the influence of PEG-6000 providing better environment for higher digestibility and hence microbial protein synthesis (Makkar, 2003; McDonald *et al.,* 2011) enhancing better utilization of the diet. This was in agreement with the earlier findings of Seng and Rodriguez (2001) who fed goats with high level of cassava foliage based diet. Thus, corroborating the assertions of Tona *et al.* (2014) who reported that the higher the FCR value, the less desirable is the diet, as the animal consumes more feed to produce a unit weight gain. This may be because the animals were able to utilize the nutrients better than other dietary treatments. PEG-6000 supplementation made the strong complexes with tannin, thereby preventing its negative effects on the dietary nutrient digestibility and utilization.

Serum biochemical indices

Dietary MSP + PEG-6000 did not significantly affect the total protein, albumin and globulin values of the experimental goats, the values obtained were within the range of values (6.30-8.50g/dL, 2.70-3.80g/dL and 3.72-4.32g/dL) recommended by Daramola *et al.* (2005); Feldman *et al.* (2002) and Veterinary Manual, (2011) respectively for healthy goats. The effect of the PEG-6000 treatment, which dissociates the bond between tannin and protein, may have increased protein digestion and microbial fermentation, as evidenced raising the level of blood urea nitrogen (BUN) values of the experimental goats across the dietary treatment (Makkar *et al.,* 1995). This process increased the amount of protein that was available in the animal's system, which invariably resulted to high protein precipitation capability, raising the BUN levels. The tannin protein complex, which prevents the protein from being available for the process of fermentation, was attributed to the lower BUN values obtained in dietary MSP + PEG-6000 at 0 and 20%. The highest BUN concentration was observed in goats fed 60% MSP+ PEG-6000 when compared to other dietary treatments. This finding suggested that the tannin protein complex dissociates after leaving the rumen and increases the absorption of amino acids from the intestine (Silanikove *et al.,* 1997). The enzyme aspartate aminotransferase (AST), which is widely distributed in the heart and liver muscles, is crucial for the metabolism of amino acids (Vojta *et al.,* 2011). Significant increases in the activity of aspartate aminotransferase (AST) values observed in goats fed 0% (21.81 µ/L) and 60% (25.65 µ/L) MSP+PEG-6000 when compared with other dietary treatments could be attributed to the residual effect of anti-nutritional factors present in MSP raising the level of the enzyme in the blood. The increased AST level suggests altered membrane permeability or some disruptive activity (Sharma *et al.,* 2001). According to Opara (2010) report, the AST values obtained in this investigation were within the usual range for an apparent healthy goat. The lowest AST values obtained in goats fed 40% MSP+PEG-6000 indicated the absence of necrosis, myocardial infarctions or hepatic metabolism; which are all indicators of good protein quality of the diets. When compared to other dietary treatments, this tends to imply that the quality of the protein obtained in dietary 40% MSP+PEG-6000 was remarkable.

Haematological indices

The experimental goats' haematological indices were unaffected by dietary MSP+PEG-6000, but the results were within the range of values (Feldman *et al.,* 2002; Daramola *et al.,* 2005; Fielder, 2016) suggested for healthy goats. This suggested that the goats, irrespective of the dietary supplement, seemed to be in good health throughout the study. The PCV values obtained among treatment groups was an indication that the animals were not anaemic. There was numerical increase in Packed Cell Volume (PCV), Haemoglobin (Hb), and Red Blood Cell (RBC) but not significantly different. Goats fed dietary 40% MSP+PEG-6000 had the highest numerical PCV, Haemoglobin, RBC, WBC, Lymphocyte and monocyte values; 30.25%, 10.28 g/dL, 11.46×10^4, 9.13×10^4, 7.00% and 2.50% respectively. The values of the White Blood Cells (WBC) and their differential counts obtained in this study were within the normal range reported for healthy goats (Feldman *et al.,* 2002; Pampori, 2003; Fielder, 2016). An increase in white blood cells (WBC) typically results from an animal's immune system reacting to an antigen, or foreign body, present in the body. This was consistent with the findings of Ahamefule and Udo (2011) observation, which reports that the inclusion of pigeon pea seed meal in the diets of West African dwarf goats led to greater WBC counts, which were utilized as a sensitive biomarker essential for immunological function and as an indication of stress response (Abdelnour *et al.,* 2019). Goats fed 20% and 60% MSP+PEG-6000 showed lower numerical monocyte counts according to the WBC counts observed in this study, but they did not display any obvious indications of stress.

Nutrient intake

The most significant factor influencing an animal's p erformance is its dietary intake (Mc Donald, 1995). However, Silanikove *et al.* (1994) found that the am ount of polyethylene glycol (PEG-6000) required to cause a minimal increase in feed i ntake by goats varied depending on the species of sh rub, indicating that different shrubs had varying anti-nutrients availability. This suggests that in order to affect animals' consumption, shrubs or diets with higher levels of anti-nutrients will undoubtedly need more PEG-6000**.** In comparison to the control group, dietary MSP+PEG-6000 enhanced the consumption of nearly every nutrient in the compounded diet. This result was consistent with the findings of Yisehak *et al.* (2013), who found that the diet supplemented with PEG-6000 had a substantial interaction effect on crude protein, dry matter, organic matter, neutral detergent fibres and acid detergent fibres. The addition of PEG-6000 to a diet high in tannins resulted in a considerable increase in the intake of all nutrients evaluated, indicating the beneficial effects of PEG-6000 (Frutos *et al.,* 2004). As the MSP+PEG-6000 inclusion level increased, so did the experimental goats' concentrate dry matter consumption increased in this study.

The availability of considerable quantities of rumen degradability protein from malted sorghum sprout in the compounded diet may have contributed to the greater dry matter intake value shown in goats fed 20% and 40% MSP+PEG-6000 based diet. However, similar effects were observed by Silanikove *et al*. (1994) when soya bean meal was supplemented with PEG in goats. The idea that the palatability of the MSP + PEG-6000 based diet, which increased rumen protein, would have contributed to the higher dry matter intake value observed in this study, is in line with the findings of Okoruwa. (2019), who found that lambs' consumption of crude protein increased their dry matter intake values. PEG-6000 breaks down tannin-fibre complexes in the diet, enabling microbial enzymes. The inclusion of PEG-6000 in the diet breaks down tannin-fibre complexes, allowing microbial enzymes to break them down (Frutos *et al*. 2004; Yisehak *et al*. 2013). Concentrate Ash intake values recorded in this study ranged significantly from 2.05 to 4.12g/d. Goats fed 20 and 40% MSP+PEG exhibited similar values but were higher than those on 0 and 60% MSP+PEG based diet. The effect of polyethylene glycol on MSP, which enhanced the availability of minerals in the experimental diet, maybe the cause of the increased concentrate ash consumption values seen in goats fed 20 and 40% MSP+PEG. The rumen fill caused by an abundance of non-biodegradable fibre in the intestine may be the cause of the low ether extract, ash, and NDF intake observed in goats fed dietary 0% MSP+PEG-6000 (Mc Donald *et al.,* 2011). The influence of PEG-6000 in combination with the provision of a better environment for increased digestibility and consequently microbial protein synthesis may have contributed to the highest consumption of NDF, ADF, and ADL recorded in goats fed 40% MSP+PEG base diet (Makkar, 2007; McDonald, 2011). The amounts of crude protein intake found in this study were approximately adequate for growth and upkeep of goats; these values aligned with the values (12%) recommended for goats' total dry matter consumption (NRC, 2007). More so, WAD goats on 20% (25.96 g/d) and 40% (26.23g/d) MSP+PEG-6000 based diet had statistically similar concentrate hemicellulose intake values but higher than those fed 0 and 60 % MSP+PEG-6000.

Nutrient digestibility

Digestibility of nutrients was relatively high in all the treatments; this could be as a result of adequate protein content in each of the treatments as a result of proportional reduction of tannin present in the malted sorghum sprout by polyethylene glycol. According to the findings of Ben Salem *et al.* (1999) who reported that increase in dry matter digestibility may be ascribed to an improvement of rumen fermentation as a result of PEG-6000 supplementation. Previous research showed that addition of protein source to the diet enhanced dry matter digestibility. Nonetheless, it's possible that greater nutritional synchronization led to the highest dry matter digestibility values obtained in goats fed 40% MSP + PEG-6000 based diet. This was consistent with the findings of other researchers (Ben Salem *et al.,* 2005; Yisehak *et al.,* 2013), who noted a considerable improvement in the apparent digestibility of nutrients (OM and CP) when PEG-6000 was added. The crude protein digestibility values observed in this study fell within the range of values (71.80- 86.84%) reported by Arigbede *et al.* (2005) who fed WAD goats supplemented diet with graded levels of *Grewia pubescens* and *Panicum maximum*. According to previous researchers (Mitjarila *et al.,* 1977; Silanikove *et al.,* 2001), tannins may result in post-ingestive malaise or inefficient in rumen dry matter digestion. Tannin has been associated with a reduction in the pace of digesta transport, which in turn slows down protein digestion and microbial fermentation (Makkar *et al.,* 1995). Diets high in tannin may not be as appealing to animals (Shinde *et al.,* 2000; Bhatta *et al.,* 2001). Thus, our results aligned with the report of Silanikove *et al*. (2001), who observed that goats willingly ingested a higher amount of Prosopis leaves treated with PEG-6000. Goats fed 40% MSP+PEG-6000 inclusion level recorded the highest NDF, ADL, ADF, and cellulose digestibility values. This could be explained by polyethylene glycol's capacity to bind tannin in malted sorghum sprout, hence reducing the harmful effects of tannins (Landau *et al.,* 2000). Thus, it improves the goats' ability to digest diet high in tannins (Pritchard *et al.,* 1998). The hemicellulose component of the experimental diet was shown to be utilized by the goats in this study, resulting in high hemicellulose digestibility values. This was consistent with the results of Weimer, (1992), who found that the microorganisms' enzymes, which are often claiming to impede animals' digestive tracts, could not breakdown hemicellulose. By forming strong complexes with tannin, PEG-6000 supplementation mitigated the detrimental effects of tannin on the digestion of dietary components.

Nitrogen utilization

Significant differences ($p<0.05$) were observed in the nitrogen utilization parameters except the urinary nitrogen losses. The nitrogen intake values (1.07-1.88 g/d) significantly increased across the dietary treatments as addition of MSP + PEG-6000 increased. The highest faecal nitrogen loss obtained in goats fed 60 % MSP + PEG-6000 could probably be due to the CP content in 60 % MSP + PEG-6000 that was not well utilized and thus excreted. This was in conformity with the findings of Schuba *et al.* (2017) who reported that nitrogen consumed in excess of animal’s requirement was excreted in urine and faeces. The nitrogen retention values obtained in this study did not follow a particular trend but ranged significantly from 52.85-77.82 % in which goats on 40% MSP + PEG based diet recorded the highest values (77.82%). Nitrogen retention is the proportion of nitrogen utilized by farm animals from the total nitrogen intake for body process, hence the more the nitrogen consumed and digested, the more the nitrogen retained and vice versa (Okeniyi *et al.,* 2010). This might have also been as a result of the amount of nitrogen used in protein deposition and nitrogen utilization in the rumen. This observation is further buttressed by the fact that the diet was well balanced in energy and protein which reduced nitrogen excretion in urine which was attributed to better nitrogen retention in goats fed 40% MSP + PEG-6000. All the animals recorded positive N-balance on the various dietary treatments. These observations suggest that the varying inclusion levels of the experimental diet were able to meet the protein requirement of the animals ascribed for maintenance and production. The values obtained for faecal nitrogen were lower than that of urinary nitrogen. This was inversely proportional with what was obtained by McDowell (1992). The retention and utilization of dietary nitrogen can be influenced by type and quality of carbohydrate present in the diet (Ali-Balogun *et al.,* 2003). PEG-6000 supplementation made the strong complexes with tannin, thereby preventing its negative effects on the dietary nutrient utilization.

Rumen fermentation

The inhibition of rumen microbial fermentation and a decrease in the quantities of acetate, lactate, and propionate may be the cause of an increased rumen pH at a high level of tannin found in MSP. Ruminal pH may be impacted by the amounts of essential oils or herbal plants utilized (Evans and Martin, 2000). They hypothesized that supplementing with 400 mg L-1 of thymol oil raised ruminal pH, but at lower doses (50, 100 and 200), it had no effect (*in vitro*). Goats fed 20% MSP+PEG-6000 showed lower rumen NH_3-N, which was linked to the tannin protein complex, which prevented the protein from being available for fermentation. The significant rise in rumen NH_3-N obtained in goats fed 40% MSP+PEG-6000 after they were supplemented with high protein feed suggested that the tannin protein complex dissociates after leaving the rumen and increases the absorption of amino acids from the gut (Silanikove *et al.,* 1997). The reduced volatile fatty acid (VFA) suggested that certain ruminal microorganisms may have been inhibited by certain free binding sites of tannins that were present in the rumen of goats fed 0, 20, and 60% MSP+PEG-6000. The enhanced fermentation caused by the particular binding of tannins with PEG is the reason for the higher VFA production in goats fed 40% MSP+PEG-6000. A similar finding was also observed by Silanikove *et al.* (1996) in goats fed PEG and foliage containing tannin. Additionally, greater pH and lower VFA levels in the rumen fluid of animals fed certain diets high in tannins imply a significant reduction in microbial activity, according to research by Silanikove *et al.* (1996, 1997).

Microbial Counts

PEG-6000 supplementation may have increased the microbial activity in the rumen, which may have contributed to the increase in total bacteria count (TBC) of the experimental goats across the dietary treatments. The fermentation of feed nutrients is improved by the rumen's increased microbial activity. As a defecation agent, tannins found in MSP can reduce protozoa population, allowing bacteria to grow in the rumen. By decreasing the number of protozoans in the rumen and their ability to prey on bacteria, this increases the efficiency of the fermentation process (Fagundes *et al.,* 2020; Roca-Fernández *et al.,* 2020). This is consistent with a study by Okoruwa and Aidelomon, (2020) which discovered that adding ginger powder to the diets of sheep and goats greatly decreased the overall protozoa. Protozoa regulate the rate of nitrogen movement in the rumen and supply soluble proteins to maintain bacterial growth (Zain *et al.,* 2020).

CONCLUSION

Based on the results of this study, it can be concluded that;

- Malted Sorghum Sprout treated with Polyethylene glycol can be included at 40% inclusion level in the diet of West African Dwarf goats as it influenced the concentrate dry matter intake and FCR.

- Dietary MSP+ PEG-6000 up to 40% significantly improved all the concentrate nutrient intake values of WAD goats in term of CDMI, CCPI, CAI and Hemicellulose intake.

- Dietary MSP+ PEG-6000 at 40% significantly improved all the nutrient digestibility values of WAD goats observed in this study.

- Addition of MSP+PEG-6000 up to 40% significantly recorded the highest nitrogen utilization parameters across the dietary treatments.

- Dietary MSP+PEG-6000 up to 40% significantly influenced all the rumen fermentation parameters as it enhanced the propionic acid (42.00mm/100mL), acetic acid (42.50mm/100mL) butyric acid (33.50 mm/100mL), total volatile fatty acids (118.00mm/100mL), total bacterial count (2.85 x 10^6cfu/mL), and total coliform count (1.45 x10^6 cfu/mL).

RECOMMENDATION

Dietary MSP+PEG-6000 up to 40% is recommended in WAD goat's diet for better output in terms of concentrate dry matter intake, FCR, improved nutrient digestibility values, nitrogen utilization and total volatile fatty acids

REFERENCES

Abdelnour, S. A., Abd El-Hack, M. E., Khafaga, A. F., Arif, M., Taha, A. E. and Noreldin, A. E., 2019. Stress biomarkers and proteomics alteration to thermal stress in ruminants: A review. *Journal of thermal biology, 79*: 120-134.

Ahamefule, F. O. and Udo, M. D. (2011). Dry matter intake and digestibility in West African Dwarf goats fed raw or processed pigeon pea (Cajanus cajan) seed based diets. *Iranian Journal of Animal Science*. 1(1): 17-21

Alli-Balogun, J. K., Lakpini, C. A. M., Alawa, J. P., Mohammed, A. Nwanta, J. A. (2003). Evaluation of cassava foliage as a protein supplement for sheep. *Nigeria Journal of Animal Production*. 30 (1): 37- 46

Aka, L. O., Ugohukwu, N. C., Ahmed, A. and Pilau, N. N. 2011. The effect of ruminal incubation of bioactive yeast (Saccharomyces cerevisiae) on potential rumen degradability of Panicum maximum and Centrosema pubescens in West African dwarf sheep. *Sokoto Journal of Veterinary Sciences*, 9(1): 28 – 35.

Aletor, V. A., Hamid, I. I., Nieb, E. and Pfeffer, E. 1998. Low-protein amino acids supplemented diets in Broilers. 1. Effects on growth performance, relative organ weight and carcass characteristics. In: Proceedings of silver Anniversary Conference Nigerian Society of Animal Production. pp: 153-154.

Arigbede, O. M., Olanite, J. A. and Bamikole, M. A. 2015. Intake, performance and digestibility of West African Dwarf goats supplemented with graded levels of *Grewia pubescens* and *Panicum maximum. Nigerian Journal of Animal Production,* 32 (2): 293-300

Babeker, E. A. and Elmansoury, Y. H. A. 2013. Observations concerning haematological profile and certain biochemical in Sudanese desert Goat. *Online Journal of Animal Feed Resources.* 3(1): 80-86.

Ben Salem, H., Nefzaoui, A., Ben Salem, L. and Tisserand, J. L. (1999). Different means of administrating polyethylene glycol to sheep: effect on the nutritive value of Acacia cyanophylla Lindl. Foliage. *Anim. Sci.* 68: 809–818

Ben Salem, H., Nefzaoui, A., Ben Salem, L., Tisserand, J. L. 2000. Deactivation of CT in Acacia cyanophylla Lindl. foliage by PEG in feed blocks. Effect on feed intake, diet digestibility, nitrogen balance, microbial synthesis and growth by sheep. *Livest. Prod. Sci.* 64: 51–60

Ben Salem, H., Ben Salem, I. and Ben Sa¨ıd, M.S. (2005). Effect of the level and frequency of PEG supply on intake, digestion, biochemical and clinical parameters by goats given kermes oak (*Quercus coccifera* L.)-based diets. *Small Ruminant Research.* 56: 127–137.

Bhatta, R., Shinde, A. K., Sankhyan, S. K., and Verma, D. L. 2001. Nutrition of range goats in a shrub land of western India. *Asian Aust. J. Anim. Sci*. 15(12): 1719–1724.

Bhatta, R., Shinde, A. K., Vaithiyanathan, S., Sankhyan, S. K. and Verma, D. L. 2002. Effect of Polyethylene glycol-6000 on nutrient intake and digestion and growth of kids browsing *Prosopis cineraria*. *Anim. Feed Sci. Technol.* 101: 45–54

Daramola, J. O., Adeloye, A. A., Fatoba, T. A. and Soladoye, A. O. 2005. Haematological and Biochemical parameters of West African dwarf goats. *Livestock Research for Rural Development.* 17: 1-8.

Evans, J. D. and Martin, S. A. (2000). Effects of Thymol on Ruminal Microorganisms. *Current Microbiology,* 41(5): 336-340.

Fagundes G. M., Benetel, G., Welter, K. C., Melo, F. A., Muir, J. P., Carriero, M. M., Souza, R. L. M., Meo-Filho, P., Frighetto, R. T. S., Berndt, A. and Bueno, I. C. S. 2020. Tannin as a natural rumen modifier to control methanogenesis in beef cattle in tropical systems. Friend or foe to biogas energy production. *Res. Vet. Sci.* 132(5):88–96.

Feldman, B. F., Zink, J. G. and Jain, N. C. 2002. Schalm's Veterinary Hemetology. Philadelphia. Baltimore, New York, London, Buenos Aires, Hong Kong, Sidney, Tokyo: Lippincott Williams and Wilkins.

Fielder, S. E. 2016. Hematologic Reference Ranges. Merck Veterinary Manual, Centre for Veterinary Health Sciences (CVHS), Oklahoma State University. Available at: http://www.merckvetmanual.com/appendixes/reference-guides/hematologic- reference-ranges. Accessed on 27/03/2017

Frutos, P., Hervás, G., Giráldez, F. J. and Mantecón, A. R. 2004. Review. Tannins and ruminant nutrition. *Spanish Journal of Agricultural Research*. 2(2): 191 - 202.

Kroes, R., Müller, D., Lambe, J., Löwik, M. R. H., Van Klaveren, J., Kleiner, J. and Visconti, A. 2002. Assessment of intake from the diet. *Food and Chemical Toxicology, 40*(2-3): 327-385.

Lamy, E., Rawel, H., Schweigert, F. J., Fernando, C. S., Ferreira, A., Rodrigues, C., Antunes, C., Almeida, A. M., Coelho, A.V. and Sales B. E. 2011. The effect of tannins on Mediterranean ruminant ingestive behavior: the role of the oral cavity. *Molecules*, 16: 2766- 2784

Landau, S., Silanikove, N., Nitsan, Z., Barkai, D., Baram, H., Provenza, F. D. and Perevolotsky, A. 2000. Short-term changes in eating patterns explain the effects of condensed tannin on feed intake in heifers. *Appl. Anim. Behav. Sci.* 69: 199-213.

Makkar, H. P. S., Blummel, M., Becker, K. 1995. Formation of complexes between polyvinyl pyrrolidones or polyethylene glycols and tannins, and their implication in gas production and true digestibility in *in vitro* techniques. *Br. J. Nut.* 73: 897–913.

Makkar, H.P.S. 2003. Effects and fate of tannins in ruminant animals, adaptation to tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. *Small Rum. Res*. 49:241

Makkar H. P. S. 2007. Feed supplementation block technology–past, present and future; (Feed Supplementation Blocks. Urea-molasses multi-nutrient blocks: simple and effective feed supplement technology for ruminant agriculture). FAO animal production and health paper. 164: 1–12.

Masafu, M. M. 2006. The evaluation of *Leucaena leucocephala* (Lam) DE WIT: A renewable protein supplement for low quality forages. PhD Thesis, University of South Africa

McDonald, P., Edwards, R. A. and Greenhalgh, J. F. D. 1995. Animal nutrition. 5th Edition, Longman Group Publications, London, 488 pp

McDonald, P., Edwards, R. A., Greenhalgh., J. F. D., Morgan., C. A., Sinclair, L. A. and Wilkinson, R. G. 2011. Animal Nutrition. 6th. Pearson Prentice Hall, Harlow, England

McDowell, L. R. 1992. Minerals in Animals and Human Nutrition. 1st Edition, Academic Press, New York, USA.

Merck Veterinary Manual, 2011. http://www.merckvetmanual.com/appendixes/reference-guides/hematologic-reference-ranges (accessed 20th December 2011)

Merck Veterinary Manual 2016. http://www.merckvetmanual.com/appendixes/reference-guides/hematologic-reference-ranges (accessed 20th December 2016)

Mitjarila, S., Lacombe, G., Carrera, G. and Derache, R. 1977. Tannic acid and oxidised tannic acid on the functional state of rat intestinal epithelium. *J. Nutr*. 107: 2113–2121.

Naumann, H. D., Tedeschi, L. O., Zeller, W. E. and Huntley, N. F. 2017. The role of condensed tannins in ruminant animal production: advances, limitations and future directions. Revista Brasileira de Zootecnia, 46(12), 929-949. http://dx.doi.org/10.1590/s1806-92902017001200009.

NRC. 2007. Nutrient requirement of small ruminants: Sheep, goats, Cervids and New world Camelids. National Academy press, Washington DC. 384 pp.

Nsahlai, I. V., Fon, F. N. and Basha, N. A. D. 2011. The effect of tannin with and without polyethylene glycol on in vitro gas production and microbial enzyme activity. *South African Journal of Animal Science.* 41(4): 337-344.

Okeniyi, F. A., Aina, A. B. J., Onwuka, C. F. I. and Sowande, O. S. 2010. Nutrient digestibility of urea maize stover-based diets as dry season feed in West African Dwarf Goats. Proceedings of the 15th Animal Science Conference Association of Nigeria, University of Uyo, Nigeria. Pp 663- 665.

Okoruwa, M. I. 2019. Feed intake, relative preference index, rumen digestion kinetics, nutrient digestibility and live weight change of goats fed selected browse plants. *Livestock Research for Rural Development*, *31*(4): 239-243.

Okoruwa M. I. and Aidelomon, E. O. 2020. Manipulation of rumen fermentation and microbial diversity for live-weight gains of sheep as influenced by ginger powder and lime peel. *Eur. J. Biol. Biotechnol.* 1(5):1–6.

Opara, M. N., Udevi, N. and Okoli, I. C. 2010. Haematological parameters and blood chemistry of apparently healthy West African dwarf goats in Owerri, South Eastern Nigeria. *New York Science Journal.* 3(8): 68-72.

Ososanya, T. O., Odubola, O. T. and Shuaib-Rahim, A. 2013. Intake, nutrient digestibility and rumen ecology of West African dwarf (WAD) sheep as influenced by pineapple with orange pulps. *International Journal of Agricultural Science*. 3(11): 862-870.

Pampori, Z. A. 2003. Field Cum Laboratory Procedure in animal health care. Daya publishing house, New Delhi, India, pp: 172- 182.

Pritchard, D. A., Stocks, D. C., O'Sullivan, B. M., Martins, P. R., Hurwood, I. S., O'Rourke, P. K. 1988. The effect of poly- ethylene glycol (PEG) on wool growth and live weight of sheep consuming a Mulga (Acacia aneura) diet. Proc. Aust Soc. Anim. Prod. 17, 290–293.

Roca-Fernández, A. I., Dillard, S. L. and Soder, K. J. 2020. Ruminal fermentation and enteric methane production of legumes containing condensed tannins fed in continuous culture. *J. Dairy Sci.* ;103(8):7028–7038

Saka, A. A., Sowande, O. S., Oni, O. A., Adewumi, O. O., Ogunleke, F. O. and Sodipe, O. G. 2016. Performance Evaluation and haematological Parameters of West African dwarf goats fed diet containing graded levels of raw and fermented malted sorghum sprout. *Nigerian Journal of Animal Science* (2): 444-457.

Seng, S. and Rogriguez, L. 2001. Foliage from cassava, Flemingia macrophylla and bananas compared with grasses as forage sources for goats: effects on growth rate and intestinal nematodes. Livestock Research for Rural Development (13) 2: http://www.lrrd.org/lrrd13/2/soke132.htm

Schuba, J., Südekum, K.H., Pfeffer, E. and Jayanegara, A., 2017. Excretion of faecal, urinary urea and urinary non-urea nitrogen by four ruminant species as influenced by dietary nitrogen intake: A meta-analysis. *Livestock Science*, *198*, pp.82-88.

Sharma, D. K., Chauhan, P. P. S. and Agarwal, R. D. 2001. Changes in the levels of serum enzymes and total protein during experimental haemonchosis in Barbari goats. *Small Ruminant Research*.; 42(2):119-123.

Shinde, A. K., Sankhyan, S. K., Bhatta, R. and Verma, D. L. 2000. Seasonal changes in nutrient intake and its utilization by range goats in a semiarid region of India. *J. Agric. Sci.* (Cambridge) 135: 429–436.

Silanikove, N., Nitzan, Z. and Perevolotsky, A. 1994. Effect of polyethylene glycol supplementation on intake and digestion of tannin containing leaves (Ceratonia siliqua) by sheep. *J. Agric. Food. Chem*. 42, 2844–2847.

Silanikove, N., Giloba, N., Perevolotsky, A. and Nitsan, Z. 1996. Effect of daily supplementation of polyethylene glycol on intake and digestion of tannin containing leaves (Quercus calliprinos, Pistacia lenticus and Ceratonia siliqua) by goats. *J. Agric. Food Chem.* 44: 199–205.

Silanikove, N., Giloba, N. and Nitzan, Z. 1997. Interactions among tannins, supplementation and polyethylene glycol in goats fed oak leaves. *Anim. Sci*. 64:479–483.

Silanikove, N., Perevolotsky, A. and Provenza, F. D. 2001. Use of tannin binding chemicals to assay for tannins and their negative post-ingestive effects in ruminants. *Anim. Feed Sci. Technol.* 91: 69–81.

Singh, B., Sahoo, A., Sharma, R. and Bhat, T. K. 2005. Effect of polethylene glycol on gas production parameters and nitrogen disappearance of some tree forages. *Anim Feed Sci Technol*. 123–124:351–364.

Tona, G. O., Ogunbosoye, D. O. and Bakare, B. A. 2014. Growth performance and nutrient digestibility of West African Dwarf goats fed graded levels of *Moringa oleifera* leaf meal. *International Journal of Current Microbiology and Applied Sciences*. 3(8): 99-106.

Vojta, A., Shek-Vugrovecki, A., Radin, L., Efendic, M., Pejakovic J. and Simpraga M. 2011. Hematological and Biochemical Reference Intervals in Dalmatian

Pramenka Sheep Estimated From Reduced Sample Size by Boat Strap Sampling. *Veterinary Archive*, 81: 25-33.

Webb, E. C. 2014. Goat meat production, composition, and quality. Animal Frontiers 4: 33–37. doi:10.2527/af.2014-0031

Weimer, P.J. 1992. Cellulose degradation by ruminal microorganisms. *Critical Reviews in Biotechnology*, 12(3): 189-223.

Yisehak, K., Becker, A., Rothman, J. M., Dierenfeld, E. S., Marescau, B., Bosch, G., Hendriks, W. and Janssens, G. P. J. 2012. Aminoacidic profile of salivary proteins and plasmatic trace mineral response to dietary condensed tannins in free-ranging zebu cattle (Bos indicus) as a marker of habitat degradation. *Livestock Science*, 144(3): 275- 280

Yisehak, K., Taye, T. and Aynalem, H. 2013. Characteristics and Determinants of Livestock Production in Jimma Zone/Southwestern Ethiopia. *African Journal of Basic and Applied Sciences*, 5(2): 69-81.

Yisehak, K., De Boever, J. and Janssens, G. P. J. 2014. Effects of supplementing tannin rich diets with polyethylene glycol on digestibility and zoo technical performances of zebu cattle bulls (Bos indicus). *Journal of Animal Physiology and Animal Nutrition*, 98(3): 431–438.

Zain, M., Putri, E. M., Rusmana, W. S. N., Erpomen, E. and Makmur M. 2020 Effects of supplementing *Gliricidia sepium* on ration based ammoniated rice straw in ruminant feed to decrease methane gas production and to improve nutrient digestibility (*in-vitro*) *Int. J. Adv. Sci. Eng. Inf. Technol.,* 10(2):724–729.